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THE LANGUAGE OF SCIENCE

ITS GROWTH, CHARACTER AND USAGE

There can be no doubt that science is in many ways the natural enemy of language

L.P.S.

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BROWSING AMONG WORDS OF SCIENCE

LATIN AND GREEK FOR BIOLOGISTS

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PREFACE

MEN have said, many times in the last eighty years or more, that they were living in a scientific age. To repeat the statement is to utter a platitude. And yet, for all its repetition, it is doubtful whether many would have been able, if pressed, to explain exactly what they meant by the remark. One thing is clear – the vague, the general implication of this parrot-phrase has been different, or has appeared to the layman to be different, at various times in the course of the century.

To-day this implication falls more strongly than ever before on the universality of the scientific outlook; scientific knowledge impinges on so many aspects of modern life that all men of any intellectual stature are to some extent scientists, learning or using the language of the laboratory.

In these circumstances it is strange that no one seems to have undertaken a broad study of the language of science. Certainly no book on language omits to mention the influence of discovery on our vocabulary, but after this perfunctory reference interest wanes, and no more information is to be found.

I believe that here there is a manifest gap in the literature of both philology and science, and this belief has prompted me to attempt the pages that follow. True, the greater the gap the greater the opportunity; but the greater also is the difficulty in writing a book which must be to some extent a pioneer. Qualities of originality, power of percipience and penetration, and a degree of

scholarship are all desirable; and desirable to an extent beyond any to which I can lay claim. Critics will notice that a proportion of this book covers ground that is already familiar to philologists, and a proportion of it covers ground that is familiar to scientists. I should like to say that this is intentional in a book to be read by philologists and scientists alike; for many in either category have not had, or have not yet had, the opportunity to study the writings of the other. Only by including the elements of both kinds of learning can I have any hope of effecting a synthesis of their points of view.

My hope is that I may have communicated to my readers some of the pleasure of writing this book, whether they are interested in science or in language or in both, or in the relations between them.

I wish gratefully to acknowledge my indebtedness to the following books and to their authors: O. Barfield, *English History in Words*; H. Bradley, *The Making of English*; V. Grove, *The Language Bar*; W. A. Osborne, *Essays and Literary Sketches*; Eric Partridge, *The World of Words*; S. Potter, *Our Language*; L. Pearsall Smith, *The English Language*; J. G. Weightman, *On Language and Writing*; C. L. Wrenn, *The English Language*.

St John's Wood, 1953 T.H.S.

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OF LANGUAGE AND OF SCIENCE

LANGUAGE is the vehicle of ideas. It is probable that the most fundamental thoughts, which are concerned with self-protection, nutrition and reproduction, can appear in the mind without the need for precise expression in words, as in fact they do appear in the minds of animals; but it is difficult to imagine how less primitive thoughts can be developed by the mind without the aid of silent language. Thus language becomes the means by which thoughts are communicated to others.

The communication is effected by words. Words are fundamentally movements of the body, with which a specific significance is associated. A nod or a shake of the head has an implication that is recognised by all. A honey-bee, returning to its hive with its crop full of nectar, can inform other bees in what direction and at what distance is the food-supply from which it has come; it does this by a series of repeated movements on the surface of the comb. The movements, called the 'round-dance' and the 'waggle-dance', are common to all honey-bees everywhere; they are interpreted in the same way by all bees and they are so recognisable by practised observers that at least one zoologist has said that it is easier to understand the language of bees than that of many members of the human race. A male spider approaches a female with a display of limbs and a

characteristic posturing which form as patent an invitation as any of the activities of a man in a comparable situation; or at the edge of a spider's web a male so peculiarly plucks and plays upon the threads that an arachnologist has said that 'clearly there is a language of touch and many spiders can speak it well'. Some other students of animal behaviour have gone further than this. An example is Dr Konrad Z. Lorenz, who during years of experiment and observation established unusually close relations with his birds, dogs and other animals. It is said of him that 'he came to understand the meaning of their call notes and their smallest gestures by which they communicate their emotions and intentions to their fellows, and he in turn was able to communicate with them'.

The words of men and women are almost wholly movements of the larynx, tongue and lips, producing audible vibrations of the air. The spoken word is thus able to reach a refinement and achieve a complexity that silent movements cannot so easily attain. Consequently, articulate sounds are dominant in human speech, and other movements are vestigial. They have sunk to the status of gestures, which may be called upon to reinforce the sounds, as in emphatic or eloquent oratory, but which may be wholly omitted, as in telephone calls and broadcast talks.

Further, human speech differs from all forms of animal speech in that it can be expressed and preserved in writing. Many wild animals do indeed mark the boundaries of their own domains or territories by means which are as effective as the trespass warnings of men, but there has been no advance comparable to the written

records which play so conspicuous a part in human life.

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It is only fair to add that this description of the origin of speech is but one hypothesis, and that not all students of language accept it. It is, however, a hypothesis that makes a strong appeal to a zoologist, who realises that vocal powers show evolution in common with other characteristics of animal life. Lung-fish can emit an occasional grunt, amphibians are the first vertebrates to express the stimulus of sex experience in a truly vocal manner, birds have so improved on this that their notes are usually described as songs, and mammals have raised it through the roars of lions, the neighings of horses and the chatterings of monkeys to the speech of man.

The armchair philologist runs the risk of not fully appreciating the significance of this. He tends to limit himself to the last manifestation, the words of man, and is likely to think of words as things that originated as scratches on clay tablets and evolved through papyrus and parchment to become print. He may know little of animal life and may believe such outworn legends as that swans sing as they die and that giraffes are wholly dumb. He gives insufficient attention to the fact that man is an animal and that neither a clay tablet nor a sheet of newsprint can be made to convey a message or express a sentiment unless special movements adapted to the purpose are correctly made.

Further, a zoologist may take the opportunity to point out that the communication which takes place

between bees or spiders, as in the examples noted above, does not represent a primitive or ancestral form of the speech of man. They are inborn activities of an instinctive nature; they are inherited and do not have to be learnt, whereas children have to learn how to speak, and English children learn a different speech from that learned by the children of other nations. This does not in any way weaken the biological hypothesis; it merely shows that communication between individuals has been independently evolved at different times and at different levels in the animal kingdom. So have other powers. For example, the power of flight has been achieved independently by insects, reptiles, birds and mammals, and there is no evolutionary relationship between the wings of a bee and the wings of a bat.

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Languages may be studied in many different ways. It is possible to investigate the letters of the alphabet, the symbols in which words are recorded, to discover their origins and hence the reasons for their characteristic shapes; it is possible to analyse the sounds of which they consist when they are spoken, and hence to discern the rules of spelling; it is possible to discover the origins of words and to trace their variations in spelling and pronunciation throughout the ages and throughout the different races of mankind; or to discuss the changing meanings of words and so to reveal an evolution of language; and again it is possible to compare languages with one another, to classify them in groups which express their relationships, their resemblances and their differences. Alternatively, it is possible to examine the

use of words to see, simply, how their arrangement and inflections enable them to convey varying meanings; or, less simply, to note their power, derived from their inherent beauty or force, their meanings and their associations, to move men to courage, to inspire them to devotion, to seduce them to folly, in fact to make them heroes, saints or criminals, or merely to make them laugh.

All these fascinating paths of scholarship have been trodden by men of many nations to produce the complex body of exact knowledge which is called philology. And at all times the study of philology is set against a background which is, in effect, the whole of human activities. Whatever men do has an influence on, and is reflected in and preserved by their language. Men have wandered as nomads on the earth, they have sailed the seas; they have hunted and fished and cultivated the soil; they have gone to war and emerged as victors or vanquished; they have exploited the resources of nature, developed crafts and practised arts; and they have amassed an immense store of knowledge. All these things they have done and are doing, and all have resulted in fresh habits of speech, and so in the growth of their languages.

Their languages, moreover, have made these achievements possible. It is important to recall that fundamentally language has two distinct aspects; it may be emotive, affective, or it may be symbolic, informative. 'And a man shall be as an hiding-place from the wind, and a covert from the tempest; as rivers of water in a dry place, as the shadow of a great rock in a weary land' is an example, and a particularly magnificent one, of the use by Isaiah of affective speech. 'In any triangle the sum of the squares on two sides is equal to twice the

sum of the squares on half the third side, and on the median which bisects it' is an example, and a familiar one, of the use by Apollonius of informative language.

All readers will probably recognise that in the mouths and in the books of the students of science, emotive language is rare, and informative language is common.

* * *

What is science? In the 1860's the implication of the word science to the mind of the ordinary man was atheism and some half-understood nonsense about monkeys; at the turn of the century it meant Röntgen rays, which made the invisible visible; after the First World War it meant wireless waves, which, putting a girdle about the earth, were to weld all civilisation into a harmonious family; and later, after a Second World War, it meant atomic bombs, which threatened to unite civilisation only in universal catastrophe. If any of these things are true, science deserves of all men an attempt to appreciate it, and to understand what science is, what it is not, and what it can achieve.

Man has always been an inquisitive creature. He has found himself in a world where life is precarious and often painful, so that he has speculated, quite excusably, about the cause of his arrival on earth, the meaning of his short and apparently futile sojourn upon it, and the destination to which he is bound when he leaves it. The results of these speculations he has collected into a mass of anecdotes, regulations, aspirations and warnings which form his religion, and the study of which is called theology. He has probed a little way, a very little way, into the rocks of his earth, into the waters of its seas

and into the air, and has recorded the results of his investigations in a mass of materialistic knowledge called science. He has mused and dreamed and sung, and so has composed a quantity of romantic inspiration, which is known as mysticism. And he has thought, pondered as deeply as he knows how, following methods which he hoped would ensure a freedom from fallacy, and would avoid the persistence of error, trying to correlate the conclusions of the theologian, the scientist and the mystic, and so has produced an immense bulk of sober wisdom which is known as philosophy.

In all these ways and perhaps in others, he has constantly and universally affirmed the truth of Nansen's explanation of the reason for polar exploration. 'Man wants to know,' he wrote, 'and when he ceases to do so, he is no longer man.'

From this description, within the confines of a single paragraph, of the nature of man's chief methods of satisfying his desire to know, the character of science in general begins to appear. It is one of man's ways. It is a many-sided product of his mind; and it has been more successful, or scientists would claim that it has been more successful, than any of the other methods of illuminating the mystery by which he is surrounded.

Science, then, is knowledge; but it is knowledge of a particular and limited kind, gathered by a particular and characteristic method. In this, the scientific method, observations and measurements are linked by hypotheses to experiments and theories. It is no part of our present purpose to explore further the successes and failures of the methods which are familiar to scientists. Were they all adequately discussed they would reveal science as

a vast product of the mind of man, overtopping the sum of its constituent sciences, and demanding of its followers a devotion and an intellectual integrity in their disinterested search for truth.

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It is, however, of first importance to argue an alternative question. If the meanings of the words 'language' and 'science' may now be supposed to have been sufficiently discussed, there remains the necessity of deciding whether there is, in fact, anything so characteristic of the terms in which scientists expound their doctrines that there can truthfully be said to be a language of science at all?

A simple way in which to try to find the answer to this question is to present a scientist and another with the same proposition and then to compare the languages in which their responses are expressed. Probably the objects most familiar to us are our fellow men, for the whole of our lives are passed in close touch with them and our own thoughts and actions are determined very largely by theirs. In consequence there exist three very well-known descriptions of man, which will admirably serve our purpose.

King David wrote a poem in Hebrew, part of which was translated thus in 1611:

What is man, that Thou are mindful of him?
And the son of man, that Thou visitest him?
Thou madest him lower than the angels:
To crown him with glory and honour.
Thou madest him to have dominion over the works
of Thy hands:

Thou has put all things under his feet:
All sheep and oxen: yea, and the beasts of the field:
The fowls of the air, and the fish of the sea;
And whatsoever passeth through the paths of the seas.

William Shakespeare wrote in 1601:

What a piece of work is man! How noble in reason! How infinite in faculty! in form and moving how express and admirable! in action how like an angel! in apprehension how like a god! the beauty of the world! the paragon of animals!

Dr L. A. Borradaile wrote in 1912:

Man is metazoan, triploblastic, chordate, vertebrate, pentadactyle, mammalian, eutherian, primate. . . . The main outlines of each of his principal systems of organs may be traced back, like those of other mammals, to the fishes.

The differences between these estimates of man's nature are indeed great, yet they resemble each other in one remarkable way, for they all make reference to animals. This cannot be a coincidence; it is significant from our present point of view because it shows that in some degree at least these three writers perceived the same aspect of man, although it had a different message for each of them and they tried to pass on that message to others in different words.

The psalmist's account is that of a mystic. He sees man first of all as a being who will bear comparison with the angels of heaven, and who because of this wields a god-like power over the rest of the organic world. He does not pause to consider either the nature

of the angels nor the nature of man's supremacy over the sheep and oxen; he accepts these mysteries quite simply as being elements in a universe which is itself incomprehensible.

Shakespeare's rather optimistic eulogy is that of a dramatist with a wide knowledge of human nature, written in the manner of a supreme artist in the use of the English language. Like the psalmist he notes a relation between man and the gods on one hand; between man and the animals on the other; but in addition he is at pains to give expression to the appearance of beauty in the varied activities of man.

It is clear that these two descriptions, though different, are more closely related to each other than either is to the third. Dr Borradaile's catalogue of adjectives gives in packed, concentrated form the opinion of a zoologist, a scientist interested above all in the study of animals. It is direct and undecorated. The emphasis falls heavily on the animal in man, to such an extent that his spiritual aspect is neglected, and angels are not mentioned.

This attempt to analyse the three quotations seems to demonstrate that the differences arise first from the fact that the three writers looking at man see different things: they have different reactions to the same stimulus. In the opening paragraph of this chapter, we saw that such reactions can be developed in the mind only by the use of language; from which it follows as a matter of logic that the reaction of the scientist has been developed, as his response has been expressed, in a language characteristic of science. It is this language with which this book is concerned.

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As the extract from Dr Borradaile shows, the language of science seems to be conspicuously indebted to Latin and Greek. This fact is perhaps its outstanding feature, and can be attributed to several causes.

The first of these is the long-continued custom of using Latin as a living language long after the fall of the Roman Empire and the end of the great periods of golden and silver Latin. Students of English literature will recall that from 1649 to 1660 Milton was Latin Secretary to the Council of State; while a scientist is perhaps more suitably reminded that Isaac Newton's *Principia* of 1689 and Carl von Linné's *Systema Naturae* of 1735–60, were written in Latin; and it is an interesting supplement to this to remember that Newton's *Opticks* of 1692 was written in English.

In truth, for many centuries any learning beyond the lore of the raising of crops and the breeding of stock meant the study of Latin and Greek, for the purpose of reading the Gospels in their original form, and the works of the commentators and theologians. The long-standing relationship between the vocations of preaching and teaching, as was seen until recent years in the preponderance of clerical headmasters, and also in the authority of the Church in all matters of social economy, formerly so widely respected and now so vestigial, trace back to this tradition.

Secondly, this study of the classical languages and their use until well into the eighteenth century must also have been due in part to their own qualities. Greek has been called the noblest form of human speech, and the Attic Greek of the writers of Athens shows a beauty and a sensitiveness that make it unapproachable as a means

of expressing the thoughts of man. Latin has slightly different qualities, which almost any passage will show. Cicero, who knew something of eloquence, spoke thus:

> Is erit eloquens qui poterit parva summisse, modica temperate, magna graviter dicere. Qui ad id quodcunque decebit poterit accomodare orationem. Quod quum statuerit, tum, ut quidque erit dicendum, ita dicet, nec satura jejune, nec grandia minute, nec item contra, sed erit rebus ipsis par et aequalis oratio.
>
> Eloquence will be his who can speak of trivial things quietly, of moderate things temperately, of grand things seriously, who can adapt his style to whatever his theme may be. When he has determined this, he will speak in the style that his subject requires, not treating great things meanly nor broad things with detail, nor the reverse; but making his manner always appropriate to his matter.

The eloquence of Cicero, the majesty of Livy and the poetic fancy of Horace share alike the force and precision that characterise good Latin. The terse directness and lucidity of Latin sentences mark them as the words of those who knew exactly what they wished to say, and said it with all the force they could command. Such qualities are attractive in any setting and are nowhere more appropriate than in the work of a scientist.

* * *

It is for these reasons that all scientific writing contains such a high proportion of Latin and Greek, a fact which deserves examination; first, because it is essentially the

hall-mark of science to-day; secondly, because there is a well-established belief that such words are to be avoided where possible.

This very wise doctrine goes back at least to the first appearance, in 1906, of that incomparable book *The King's English*. It will be remembered that the authors commended their readers to:

1. Prefer the short word to the long.
2. Prefer the Saxon word to the Romance.

This advice was repeated by Prof. A. Quiller-Couch,[1] at Cambridge on 29th May, 1913, and again by Sir Ernest Gowers in 1948. Students of English literature are familiar with many examples of the power that lies in short words; I doubt whether any of them is better than the one I quote here, choosing it because it is a great favourite of mine and because it has an educational and scientific tinge that justifies its appearance in this book. Years ago the then Asiatic Petroleum Company adopted the practice of employing classically educated men in preference to others, and a director of the company was once asked to explain the reason for this. His perfect answer was, 'They sell more oil.'

The advice to use short Saxon words is, however, offered to less experienced authors by competent writers of what must, in this connection, be called literary English, in distinction from scientific or

[1] A memory that will not be denied. There were years when both Sir Arthur Quiller-Couch and Sir J. J. Thomson lectured on Fridays at noon, and with a fearful joy at least two young physicists used to cut the latter, whom in any case they could but partially understand, in order to sit at the feet of the former. Anyone else who has listened, as they did, to 'Q.' reading the 107th Psalm will agree that their choice was a wise one.

technical English; it cannot be offered with the same emphasis to scientists, because it is advice which cannot be followed. There are not enough monosyllables in the vocabulary of science to enable them to do so. Words like tin, or ohm, or gene are exceptional.

The long words of science are justified because they are unfamiliar. This seems to be a doubtful recommendation, and one which suggests that the scientist takes a pride in writing pages that are deliberately obscure. This is not so.

First, the words of science are often made so as to be self-explanatory because they have obviously been derived from roots that have only to be translated. What, for example, could pericardium or hypodermal mean, other than round the heart or under the skin?

Trouble may arise for the modern students who are taught science instead of the classical languages, whereas their fathers learned classics first, and science afterwards. Dr Victor Grove, in his enchanting book *The Language Bar*, has painted a heart-rending picture of the unfortunate medical student handicapped in his acquisition of a knowledge of the human body by his encounters with words like extravenal, infrahyoid and opisthognathous. The young German, he says, has by comparison an easy time of it. His language readily builds up into complexes like *Herzbeutelwassersucht*, or heart-bag-water-sickness, which is (or isn't it?) so much easier to use than hydrocardiac. But when the German writes of the *Unentwickelteliebensgefrucht*,[1] or not-unrolled-fruit-of-love, one is inclined to suggest

[1] As has been done, even though a modern writer would separate adjective and noun, or much more probably use the word Embryo.

that if this is clearness and simplicity, then one turns with relief to the dark obscurity of foetus.

Of course the truth is that the student of science very soon learns enough Latin and Greek to enable him to understand his particular vocabulary and that this very necessity helps him to remember it. The Greek language, like the German, is well suited to the production of compound words.

Secondly, the apparent unfamiliarity of scientific words, the air they have of belonging to a specialised type of thought and language, sets them apart, in some way, from the speech of everyday life. This is an advantage to the users of both languages. Shapeless and amorphous are literally the same, sleeplessness does not seem to be very different from insomnia, yet in each case both words have their appropriate uses, and the English language is the richer because both are available. It is not true to say that either language can be translated into, or replaced by, the other without loss. The loss may be small, if hypogeal is replaced by underground; it is much greater if hypostatic is translated into understanding. It may even be complete. Kipling once told us that,

The Colonel's Lady an' Judy O'Grady
Are sisters under their skins.

His meaning is lost if a scientist describes them as subcutaneous siblings.

Thirdly, the strangeness of the words of science gives them a constancy of meaning unmodified by association, a feature of much greater linguistic importance than those just mentioned and one which is treated with the greater fullness it deserves in Chapter 4.

Instead, therefore, of complaining of the saturation of the language of science by those of Rome and Athens, their assistance is to be appreciated. It is of some interest to see how much the scientist really uses them, and to what extent he has availed himself of their help. The three passages quoted above from the Psalms, from *Hamlet*, and from the *Manual of Zoology* can easily be analysed into words of Greek, Latin and Anglo-Saxon origin, and their proportions compared. When this is done, the results are:

	GREEK	LATIN	ANGLO-SAXON
	%	%	%
David	1	5	94
Shakespeare	5	20	75
Borradaile	24	15	61

Another comparison is also worth making. When once the admission of Latin and Greek has become recognised as desirable, it is of interest to enquire into the relative values of the two tongues. I have done this in an earlier book, where I have given the result of inspecting a column of thirty consecutive words taken from the index of one of the most widely-used text-books of biology of the day. The result was that 'there were traced two Latin verbs, eleven Latin nouns, four Greek prepositions, five Greek verbs and twenty-six Greek nouns. This shows that Greek is more used than Latin, nouns are more used than verbs and prepositions are more used than adjectives or adverbs'. The dominance of Greek in science needs no further emphasis.

* * *

Yet, amid these many references to the classical tongues, it should not be forgotten that the language under discussion in this chapter is English, and that English is spoken by about two hundred and twenty-five million people, of whom only fifty million live in Britain. By far the most important fraction of the remainder live in America, a fact that cannot be overlooked in any discussion of the language of science.

Many lovers of the English language are accustomed to eye with disfavour the part played by America in its development. They hear in conversation, or at the cinema, a number of phrases that fall strangely on their ears and they do not welcome these importations as additions to our vocabulary. Many of these innovations have indeed a vivid directness which seems to distinguish them sharply from the quieter manner of our traditional prose, but those who either smile or shudder at them are in danger of forgetting two important points.

The first is that many 'Americanisms' are delightfully apt: so often they express a thought so tersely, so emphatically, that they give more pleasure than pain to the appreciative listener. The pleasure they give is almost indistinguishable from the pleasure that comes from the directness and lucidity of the sentences in Latin prose which we have already extolled. In fact the habit of indiscriminate condemnation of all new forms of speech that reach us from across the Atlantic is merely narrow-minded.

Secondly, it is forgotten that many of these phrases are no more than temporary catch words. They have their vogue, during which they are worked to death;

they vanish, and leave no trace. They have done our language no harm at all.

Thirdly, and by far the most important, these products of conversational enthusiasm seldom appear in serious written work. After all, it is only the rare and perhaps remarkable phrase which is dubbed an 'Americanism' and which tells the hearer that the speech to which he is listening did not originate in England. These eccentricities or, if that is too strong a word, these exuberances disappear when the language comes to be written. There is, as we all know, a difference between the prose of a leading article in *The Times* and that of the daily conversation of its readers; probably the difference between the language of *The New York Times* and that of its readers is rather wider.

* * *

These are elementary principles, but they lead to the fact that between intellectual work written in Oxford and Cambridge and intellectual work written in Yale and Harvard, there is remarkably little difference, and perhaps no more than is traceable to different individualities with correspondingly different styles. Now the language of science is almost wholly a written language, whose words and phrases are seldom distorted in the rough and tumble of everyday speech. Hence it follows that the scientific writings that come out of America differ in language very little from those produced in Britain. Some differences there must be, but, in the mathematician's term, they are 'of a negligible magnitude'.

Most scientists who have had to read any quantity of

American science will agree that this is so. The austerity of tone that is characteristic of scientific writing obscures any national differences, and as one reads one almost immediately loses any impression that one is reading the words of an inhabitant of another continent. To confirm this view, a couple of paragraphs of American science are here quoted.

Prof. A. A. Michelson wrote in 1903:

> This unsteadiness of the image is the most serious difficulty with which astronomers have to contend; there is no instrumental remedy. The best that can be done is to choose an appropriate site, and it seems to be the general opinion of astronomers that such a site is best chosen on some very high plateau or tableland. By some it is considered that a high mountain top is a desirable location, and there is no question that such a site possesses very marked advantages in consequence of the rarity of the air.

Prof. Alexander Petrunkevitch wrote in 1923:

> Taxonomy is the mirror of Evolution. In it the relationship of forms is reflected, bringing us face to face with the results of past processes just as Physiology and Genetics reveal to us inner activities of living organisms. It is the supreme effort of the human mind to bring into a natural system knowledge derived from the study of Morphology in its widest sense. Gross and microscopic anatomy, embryology, behaviour and instinct, palaeontology, geographical and geological distribution – nay, even physiology and chemistry – contribute to the building of a system wherein the

> breadth and depth of our knowledge find their expression. Only limitation of knowledge makes the system imperfect . . . as in a poor mirror the image may be distorted, so in a system built up by a taxonomer the relationships may be wrongly represented. The smaller the knowledge, the greater the distortion.

To this fact of the close similarity between scientific English and scientific American there must be added the great and increasing interest in science taken by the American public as a whole. This general level of interest is certainly higher than in Britain. It fosters and is fed on a copious supply of scientific literature of all kinds.

Apart from the normal flow of text books common to all intellectual works, there is a constant stream of official or sponsored pamphlets, bulletins and circulars, dealing with the problems of agriculture, forestry, nutrition and health, and all the many manufactured and commercial processes which have a foundation in pure science. There are also journals specially devoted to popular science.

With all this the average American has little chance of not being brought into close contact with the science of the day, so that any discussion of the language of science should constantly remember that the language is written and read in America, and that from the point of view of the scientific philologist the two sides of the Atlantic are virtually indistinguishable.

It will not be out of place to conclude this first chapter with the statement that in having the English language as their own both nations are fortunate, perhaps more fortunate than they generally realise. Whatever may be

the virtues that are claimed for Greek or Latin, there can be few occasions when either of these languages, or any other, has been able to surpass the appeal, whether it be emotional or intellectual, of the best English prose. The greatest living Englishman said, at one of the greatest moments of his career:

> I have nothing to offer but blood and toil and tears and sweat. We have before us all an ordeal of the most grievous kind. We have before us many long months of struggle and of suffering. If you ask what is our policy I will say it is to wage war – war by air, land and sea, war with all our might and with all the strength that God can give us, and to wage war against a monstrous tyranny never surpassed in the dark and lamentable catalogue of human crime. That is our policy. If you ask us, 'What is our aim?' I can answer in one word – victory: victory at all costs, victory in spite of all terrors, victory however long and hard the road may be, for without victory there is no survival. . . . I take up my task in buoyancy and hope. I feel sure that our cause will not be suffered to fail among men. I feel entitled, at this juncture and this time, to claim the aid of all, and I say, 'Come then, let us go forward together in our united strength.'

The speaker of these well-known words is universally recognised as one of the greatest writers of modern English. In the example just given he lends support to the claim that it is a language that few can equal and none surpass.

2

THE WORDS OF SCIENCE

WORDS, it was said in the previous chapter, perhaps took their origin from bodily movements with which specific associations were connected. This was their primitive form. The evolution of words, which limited them more and more to audible movements of the lips and tongue, transferred the emphasis from the movement to the association or meaning, with the result that there is always a danger of forgetting that a mere word, or symbol, as such, has no meaning apart from that given to it by its user.

At this point almost everyone who writes of the matter quotes two or more lines from the well-known Jabberwocky, beginning,

> *'Twas brillig, and the slithy toves*
> *Did gyre and gimble in the wabe.*

He does this because these lines are accompanied by a conversation between Alice and Humpty Dumpty and the two together provide by far the best available exposition of the relation between a word and its meaning. It is also familiar to every reader.

As an alternative, consider the complaint once made by a Worcestershire farm labourer: 'Thiccy pesky maggots ev cost I an oxsheard of varges.' This requires, in proportion, just as much word for word explanation

before the reader becomes aware that it implies that, 'Those pernicious magpies have cost me a hogshead of crab-apple cider.'

If, therefore, there were to be found no more than an arbitrary or a traditional relation between a word and its meaning, it should follow that, in the interests of convenience as well as common sense, each word should have one meaning and only one. And of course this is not so. For example, biology is often described, with more brevity than accuracy, as the science of life[1]; but the word 'life' may be used in everyday speech in several ways. Sometimes it refers to the span of man's appearance on this planet, either in the sense of its duration – 'Brief life is here our portion' – or of its character – 'A busy life is a happy life' – or again it may mean the story of that appearance in a biographical sense – 'The life of Shackleton'. None of these meanings is the same as the biologist's (whatever that may be).

The word 'life', therefore, is not a single or elementary symbol, and there is nothing strange in the fact. It is a consequence of its age. Many words of great antiquity have failed to produce the offspring necessary to enable them to keep pace with the growing complexity of thought, so that there are many instances in the early development of language in which widely divergent lines of thought are designated by the same word. Were our language to be reconstructed in a rational manner, these different meanings would certainly be expressed by different symbols. Different symbols, new words,

[1] 'This is misleading. Science is not the study of abstract nouns.' L. T. HOGBEN.

could be obtained by making use of the corresponding words of other languages or by making them up, composing or inventing them by any method that seemed to be simple and sufficient.

This elementary discussion of the meanings of words forms an introduction to the words of science. There are many words of long standing which the scientist has been accustomed to use with a new and special meaning, not necessarily the same as that of the ordinary man. There are others which, in the same way, existed in the languages of foreign countries, and which because of their unfamiliar sound were admirably suited for inclusion in the special vocabulary of science. Finally, there is the largest group of all, the words composed by scientists themselves for their own purposes. Each of these three categories must be surveyed in turn: they may be called:

1. Borrowed words.
2. Imported words.
3. Invented words.

BORROWED WORDS

The early scientists, no less than those of to-day, found that their investigations were leading them into realms of thought which, hitherto unexplored, produced ideas for the expression of which no words were available. Their custom was to take a word from the ordinary speech of the plain man and to use it themselves with a meaning which might or might not be the same as its customary one.

The word 'life' which has just been mentioned, is a good example, for in a simple case like this the scientist

is scarcely to be blamed. The word has several everyday uses and no great harm is done when the biologist uses it to denote the characteristic activities shown by protoplasm. It is true that some of the chaos and doubt in modern biology can be traced to the fact that the biologist is unable to give a clear definition of the word, so that it may almost be said that he does not really know what it means; but to this he is justified in replying that the plain man does not know either, and that both should be content to use it as a short symbol in which much mystery is concealed.

So, too, do the mathematician and the astronomer use the word 'time' – a fundamental component of our consciousness, almost incapable of definition. When it is used in practice, it refers to nothing more than an arbitrary pointer – reading, which is as useful to the physicist in his measurements as it is to the citizen who has to catch a train or meet a friend. Anyone, scientist or other, is welcome to a symbol like this, to make what use of it he can.

The physicist adopted, rather unfortunately, the word 'current' when he described the changed properties of a wire connected to a voltaic battery as an electric current, and to-day we still mystify our young scholars, who excusably think of a current as something flowing, by telling them that an electric current consists of electrons moving the wrong way. Again, in 1827, Dr G. S. Ohm discovered the constancy of the relation between electromotive force and current, and, also rather unfortunately, gave the ratio the name of 'resistance'.

The botanist has given meanings of his own to such

common words as 'fruit' and 'berry'. He insists that a fruit is the product of the fertilised ovule of the flower, which is true in just the same way as it is true that salt is a salt. But the botanist finds himself compelled to describe as fruits many objects which a seedsman calls seeds, such as the grains of maize or oats, and many others, like acorns, to which no ordinary man would dream of applying the word: and makes more trouble for himself by having to describe an apple as a false fruit and deny that the luscious strawberry is a fruit at all. Certainly, he will say, it is not a berry; and, pressed to explain what he means by berry will give a definition which makes berries include oranges and bananas.

These methods of the press-gang and the concentration camp, if reprehensible, are not so outrageous as the habit of seizing an unsuspecting word and forcing it to do work for which it has no qualifications. The mathematical physicist is guilty of linguistic rape of a family of related words – 'force', 'work', 'power', and 'weight'.

In mechanics, force does not mean strength, as it does when the ordinary man says, perhaps, that he is impressed by the force of an argument. It is given a rather intricate definition, which seems to say no more than that a force is a push or a pull, and since in physics all things must be measured it acquires, from Newton's Laws of Motion, a quantitative sense which makes it the product of mass and acceleration. This, of course, is quite different from anything that the word force implies in everyday use.

This first step leads, unavoidably, to others. A weight, one is surprised to learn, is not only the familiar block

of metal with a ring on top, nor the object which athletes 'put', but a force. This is logical and inevitable, because things fall under their own weight with an acceleration (due to gravity), so that the weight of a thing has to be the force with which the earth attracts it.

'Work' gives more trouble, because the physicist has decided that a force works, or does work, only when it moves something. I may push and pull in vain at some immovable obstacle, make myself hot and tired by my efforts and yet find that mathematically I have done no work. But if I seize the dangling reins of a runaway horse and pull them, and find that nevertheless the animal continues on its course, I have had work done on me, and I, panting and dishevelled, have done less than no work.

After this it is quite easy to accept the idea that power has come to mean the rate at which work is done; or that metals suffer from 'fatigue', or that oils can be made to 'crack'.

The scientist cannot be acquitted of felonious intent in cases like these, where he changes or restricts the meaning of the word, and he is not blameless when he takes an ordinary word and expands or widens its meaning, so that a single thing gives its name to a group or category.

'Salt', for example, is a material that is essential for human beings and animals, and has a long association with social history. Its name appears in our language both in words – salary – and phrases – 'worth his salt' – and, so important was it, all over our maps as well – Salford, Saltash, Saltburn, Saltdean, Saltford. The chemist, however, uses the word to denote a class of

compounds, which he defines as the products of replacing the hydrogen of an acid, wholly or in part, by a metal or a metallic radicle. Common salt, rock salt, sodium chloride, is a compound which comes within the terms of this definition, and only to this limited extent do the salt of the grocer and the salt of the chemist mean the same thing.

The foregoing remarks can be met by the contention that if new words had been proposed for these and other ideas, scientists would still be obliged to learn their definitions, and that it does not much matter if the words thus technically defined have other meanings. It might not do so if words were passive and powerless, but words are not the inanimate things we might wish them to be. They are able to lead men astray, even when the men are scientists.

The biologists, for example, trying to understand the nature of protoplasm, detect that an organism grows longer and almost invariably they discuss, as parallels, the growth of a crystal and the growth of a chemical garden. Yet it is surely obvious that the growth of a crystal is not in the least like the growth of an animal, nor the growth of a chemical garden in any way like the growth of a plant. Even to think of comparing them is to confess oneself to have been led astray by the fact that the same word has been used for them all. It is another example of the early failure of language to develop quickly enough to express different ideas by different symbols; and the futility of comparing any of these growths with the growth, shall we say, of confidence in ultimate victory is obvious. We do not wish to compare the circulation of the blood with the circulation of the

news, nor the delivery of a baby with the delivery of the evening paper.

* * *

Although the borrowing of words from everyday speech is likely, as in the examples given above, to lead to some confusion and to justify some criticism, there is a group of borrowed words which fall into a different category. These are the words which after they have been borrowed have become so widely used and so familiar in their new context that, to varying extents, they have thrust their origins into oblivion.

An example is the word parasite. The Greek parasitos was at first an adjective, and meant feeding beside; it was applied to one who fed beside the same table as another. In Elizabethan English the parasite was scorned; he fed at his companion's expense and was, as we might now say, a toady, a sponge or sycophant. Thus Shakespeare:

> *You knot of mouth-friends*
> *Most smiling smooth detested parasites.*
>
> TIMON OF ATHENS III, VI

The biological use of the word, meaning an organism that lives in or upon another, robbing it of part of its food or consuming part of its tissues, dates from 1727, nearly two hundred years later. To-day this is by far the commoner use of the word; most people hearing it, think of fleas, or lice or internal worms, or of ivy strangling a tree; when they hear it applied to a 'spiv' they tend to think that this is a metaphorical use of the word, whereas it is in fact the original one.

A complete list of words which in this way have

become accepted as essentially scientific, while a history of obsolete pre-scientific usage lies forgotten behind them, would be a long one. Among the most interesting and surprising are the following:

Conceptacle	1611	A receptacle or cavity.
	1835	The reproductive organ of lower plants.
Corpuscle	1660	A small particle or small body.
	1741	The constituent of vertebrate blood.
Cotyledon	1545	A cup-shaped cavity.
	1776	The seed-leaf of flowering plants.
Dialysis	1586	A statement of alternative propositions.
	1861	The separation of crystalloids and colloids.
Diastema	1694	A musical interval.
	1854	The space between two kinds of teeth.
Diverticulum	1647	A byway or bypass.
	1819	A closed tubular process.
Efflorescence	1626	A period of flowering.
	1788	The loss of water of crystallisation.
Gynaeceum	1610	Women's portion of a house.
	1839	The female organs of a flower.
Halteres	1533	Weights held in the hand by jumpers.
	1823	The knobbed balancers of Diptera.
Hilum	1659	A very small thing, a trifle.
	1753	The attachment-scar of a seed.

Meiosis	1577	An understatement or litotes.
	1915	The separation of the chromosomes.
Pollen	1523	Fine flour or other powder.
	1760	The male element of flowering plants.
Pulvillus	1706	A small cushion.
	1826	The pad or process on insects' feet.

IMPORTED WORDS

These are the words taken into the language without change in spelling or in meaning. The importation of words is naturally very common in English, and ordinary speech includes such examples as pergola, potato, pyjamas, banana, bungalow, balcony and countless others. These, of course, are not derived from classical sources; but a great many other words in our everyday vocabulary are unchanged Latin, words such as index, major, simile, pauper and neuter.

With the established tendency, already noted, to make new scientific words from Latin or Greek words, the scientists adopted this method without hesitation. One of the comments which has been made by Dr Henry Bradley on the growth of our language at the time of the Renaissance is that, 'the whole Latin vocabulary became potentially English'. From the scientific point of view that statement is no exaggeration but is an almost exact statement of the position, hardly less true to-day than it was four centuries ago. During all that time the pages of the Latin dictionary have been open to scientists, who have taken unnumbered words directly from them.

Unaltered Greek words are not so many, but examples are nevertheless to be found without much difficulty.

The following is a list of some of the words thus imported without any changes, except those necessitated by the conventions of transliteration from Greek into the vocabulary of science.

LATIN

atlas	genus	nucleus
axis	hilum	ovum
bacillus	humerus	pelvis
calcaneum	humus	pollen
calcar	hydra	pubes
cerebellum	ileum	pupa
cerebrum	labium	radius
cloaca	labrum	rostrum
coitus	lamina	saliva
corolla	larva	scapula
cortex	latex	semen
femur	lomentum	seta
fibula	maxilla	species
flagellum	medulla	stamen
focus	medusa	tibia
fulcrum	meniscus	vertebra

GREEK

amnion	iris	soma
astragalus	larynx	stigma
cotyledon	nectar	telson
genesis	peripatus	thallus
hibiscus	pyrites	thorax

These lists make no pretence to be complete; it would probably not be difficult to double them. It may be noted that many of these words are used in science not only with the same spelling, but also with the same meaning. Also that they belong much more often to the biological than to the physical sciences.

INVENTED WORDS

It must be admitted that the words included in the two categories of borrowed words and imported words form but a small proportion of the vocabulary of science. This is not due to any linguistic conscience on the part of the scientist, but to the fact that the advance of science has for a hundred years or more been so rapid that neither English nor all the languages of Europe could supply sufficient words for its needs. And, of course, many of its needs were unsuspected before the scientist uncovered them by his revelations of the nature of the physical world. Hence the scientist made his words himself, and by adopting this practice lifts us into a clearer atmosphere, in which the words of literary English do not suffer imprisonment or mutilation.

There is a long historical tradition behind this process. It must be remembered that for generations after the Norman Conquest the language of the English court was French, not the Anglo-Saxon of the masses. French phrases survive in many corners of government, for example in the phrase LE ROI LE VEULT, and the extensive influence of French on the language of the country was responsible for the old remark that 'English is only French badly pronounced'. In the language of science this Gallic tradition is not obvious, but it can be

detected. For example, the word heredity is derived from the Latin hereditare, but it bears a form which betrays a more or less obvious consciousness of the French *hérédité*. Such words as fluidity and gravity are similar instances. The man who supplies or suggests a useful name for a new phenomenon, fact or anything else is doing his fellows as real a service as the man who discovers, applies or explains it. In the first decade of the present century some mysterious constituents of adequate diet were recognised and were referred to as accessory food factors. How great should be our present gratitude to Dr Kasimir Funk, who, in 1912, invented the magic word vitamin. In the forty years of its life it has saved much time and labour, and a lot of ink.

In this task of word creation the scientist has always turned to the languages of Greece or Rome, and still does so. Something of the historical development of scientific English will be found in the next chapter, and it is hard to give an example of a modern scientific word derived from any language other than Latin or Greek. This custom necessarily presupposes in the scientist some knowledge of the classics, even though it be no more than an ability to read the words in a Greek lexicon. In the absence of this, the scientist must ask for help from others; it is well known that after Michael Faraday had finished his basic researches on the phenomena of electrolysis, he appealed to the Rev. William Whewell, Professor of Moral Philosophy at Cambridge, for suitable words with which to describe his results, and in 1833 the now familiar terms anode and cathode, anion and cation came into existence in this way. Faraday's method cannot be too strongly recommended:

most pure scientific research is carried on in the laboratories of universities, and one of the advantages of university life is that there is always an expert, close at hand, to supply the answer to every problem. A closer collaboration between the scientist and the classic might discourage the appearance of such words as tachyauxesis.

A most interesting comparison may be made between the scientist who has made a discovery and the literary writer who wishes to describe some event or new idea which has inspired him. Both writers are in positions, or in mental conditions, which seem to them unique, they have something to say which no one else, as they believe, can say as well as they. The writer of literature must try to do this in familiar words, words so well known to his readers that they will be able to understand his point of view, and if not to agree with him, at least to realise his attempt to relieve the inward tension that his experience has set up, and to sympathise with his fervent belief that, shall we say, his Desirée is the most wonderful woman the world has seen.

His success in doing this depends entirely on his choice of the right word, on its selection from among the many almost synonymous yet faintly different words which crowd into his mind, and even in his inspired, hyperaesthetic state, the choice is a hard one, and may take him a long time.

* * *

The scientist is in a much more fortunate condition. He need waste neither time nor emotion in choosing the word he wants; all that he needs to do is to invent it

and, having invented it, to define it so that his successors may know in what connection they may use it. It is surprising now, when biology is so familiar a word, to recall that Jean B. Lamarck, as recently as 1815, found that there was no word to describe the general scientific study of living organisms, and suggested *'biologie'*. There is obvious chemical history in the now familiar word 'isotope'. Mendeleef first adequately described a natural classification of the chemical elements, whereby their names could be usefully inserted in the spaces of a ruled grid. Later research, largely stimulated and guided by this same periodic table, suggested to F. S. Soddy that sometimes two different substances were in fact occupying the same place, and these he quickly, one might say inevitably, called isotopes.

In the invention of such words as these the scientist has had nothing to consider except intelligibility. Usually the best scientific words are intelligible, at least to the extent that they disclose something of the nature of the things they describe. The Streptoneura are obviously animals with twisted nerves; the Margaritifera are the bearers of pearls; even a monster like hippocancriform may possibly be interpreted as horse (shoe) crab shaped.

Further, the scientist is fortunate in that usually his words are accepted by his fellow workers, and that they establish themselves in the scientific vocabulary because they fill a need. Any one with a smattering of Latin and Greek can make up words, but they may never pass into the currency of ordinary use. A well-known literary example is Ruskin's 'illth', a scientific one is Dr Marie Stope's 'erogamic'. I have in the past seen solvers of

cross-word puzzles described as cruxverbalists and lovers of islands as insulaphiliacs; both these classes of persons are numerous, but the words suggested for them have never spread into the language because they are unnecessary.

Very possibly it is not inaccurate to say that every writer has at one time or another either invented a word or wished that he had the courage to do so. Most certainly every scientist who takes a share in the advance of science finds himself compelled to do so. The methods are various, but nearly always the words that establish themselves are acceptable because they describe some characteristic of the things to which they refer. The German chemist Reichenbach invented the word paraffin in 1830 because the hydrocarbons which he was investigating were surprisingly inert. They showed parum affinis, or small affinity, for other substances. Or again in 1850 Liebig produced a new compound by oxidation of alcohol, and from the words alcohol dehydrogenatum comes the name aldehyde. One of the conspicuous features of these simple compound words is the frequency with which several useful components have been enlisted. Anyone, without pausing to think can recite a series like telegraph, telegram, telescope, telepathy and television, but may well be surprised to learn that in *The Shorter Oxford English Dictionary* not six but fifty-seven such words are given. This fact may be convincingly supplemented by the information that from the same source may be extracted twelve words that begin with phono-, thirty-five compounds of pyro-, forty-four of thermo-, and as many as fifty-four compounds of photo-.

This leads to a consideration of the frequent use of a well-worn series of prefixes. In everyday speech, the negative prefixes a-, in-, non- and un- are common enough, and of course they are equally frequent in science. Probably the use of prefixes is more often found in scientific words than others; and probably the reason for this is the great convenience that follows from the existence of so many of these words in contrasting pairs, for example:

infra-red	ultra-violet
anabolic	katabolic
introrse	extrorse
intra-cellular	extra-cellular
endoderm	ectoderm

and many others. Another pair of words, the distinction between which is now of greater importance than formerly, is supersonic and ultrasonic. The first means moving faster than sound, the second refers to sounds of so high a frequency or pitch that the human ear cannot detect them. In this connection, it is interesting to hear the younger generation describing objects or achievements that evoke great admiration as 'absolutely supersonic', just as if their predecessors' 'super' were only a contraction of this precious new word!

A number of other prefixes are in practice almost unknown outside the scientific words, and again these are found in pairs or comparative series. Homozygous and heterozygous; micronucleus and meganucleus; epiblast, mesoblast and hypoblast; orthophosphate, metaphosphate and pyrophosphate, all these show how prefixes play an essential part in the scientist's vocabu-

lary. And because science is so largely concerned with measurement and counting, prefixes which are concerned with numbers form a large group. They range from none to a thousand, as in Apoda and Millipede, from a few to a lot, as in Oligochaeta and Polychaeta, and occur for many of the numbers themselves in both Latin and Greek:

univalve	monoxide
bivalent	dipropargyl
ternate	tridymite
quadruped	tetradynamous
quinate	pentadactyl
sexfid	hexapoda
septibranchia	heptathele
octonoculina	octopus

Perhaps the best conclusion to this section on prefixes in scientific words is the statement that the great *New English Dictionary* devotes seventeen columns to words beginning with hyper-, and twenty-seven columns to words beginning with hypo-.

★ ★ ★

The narrow view, or perhaps the common-sense view, of the three categories of scientific words mentioned above, is that only the last, the invented words, are really scientific words at all. The others are trespassers. A scientist's use of 'salt' or 'work' in some queer sense of his own does not make these words scientific. Bicyclists often use toothbrushes to clean chains and hubs, but this does not make toothbrushes into cycle-accessories. On the other hand, words like catalysis, calyptrogen and

commensalism are seldom, if ever, used by any but scientists; and the general character common to all these strictly scientific words must be discussed.

By far the most important characteristic follows from this limitation of these words to scientific uses only. Scientific knowledge is spread almost entirely by the printed word which is read by the learner; it never depends wholly, as did the knowledge of the ancients, on the spoken word which was heard by the listener.

One consequence of this, and the least important, is that there is often an uncertainty about the pronunciation of these words, a difficulty – if difficulty it be – which no one seems to have thought it worth while to tackle. A familiar example of this is the term of the tissue in plants which is named parenchyma. Some botanists pronounce it trochaically, with accents on the first and third syllables; others follow an arbitrary rule which insists that all accents should fall on the antepenultimate syllable, and so stress the en; others again drop the first 'a' and call it prynchyma, with accent indifferently on either the first or second 'y'.

Manifestly the less frequently a word is used the more diverse is opinion likely to be about pronunciation, and the less is it going to matter. For example, female spiders receive sperm and lay their eggs through a sculptured orifice known as the epigyne. I cannot recall an occasion on which I have heard two men pronounce this word in the same way. Sometimes it has three syllables, sometimes four; sometimes the first 'e' is short, sometimes long: sometimes the 'g' is hard, sometimes soft; and three pairs of alternatives give 2^3 or eight possible ways in which epigyne may be sounded.

The second consequence of restriction to print is that scientific words remain unchanged in form or spelling. Words that are frequently used in speech are liable to alteration; the common example is the change of a napron to an apron. Others are the change of l'ambre to lamber; adimant to diamant – diamond; Balducca to Bagdad.

Thirdly, scientific words do not change their meanings in the course of centuries, as many ordinary words do. This singleness of meaning, this constancy in form and function generation after generation, give to scientific words a character which distinguishes them sharply from other words, but relates them to the symbols of mathematics. The comparison has been made before. Mathematical symbols, such as $+$ or $\int$, expressions like $1/\sqrt{x}$ or $x^{-\frac{1}{2}}$, formulae like $v = \frac{4}{3}\pi r^3$, have only one possible interpretation; they have all been in existence for a very long time, and it is unlikely that any mathematician will ever suggest that they should be changed. In consequence it is said that the language of the scientist should be compared to the symbols of the mathematician.

Words usually change their meanings as a result of social or other changes in the lives of the people who use them. This change of meaning, which may be slight or which may in time become quite considerable, is described by philologists as a change of associations; that is to say, it is a change in the picture which the word evokes in the mind of the speaker, hearer or reader, a change in the shade of meaning or, as Prof. Potter has happily termed it, in the penumbra of meaning.

For example, until 1913 the word casualty meant no

more than a mischance or accident, resulting in injury or death, but between 1914 and 1918 it acquired a deep emotional significance for the British people, it came by personification to be more generally applied to the victims of misfortune and has never lost its heightened appeal. Similarly the years 1939–45 gave to the word utility an implication that is quite distinct from its original one of usefulness.

Many philologists look upon this process as the life-blood of their subject. No language, they point out, is static, but is a growing, living entity which evolves in a manner closely comparable to the evolution of animals and plants. It is in just this respect that the relative constancy and stability of the words of science makes them describe science as the enemy of language, as though it were a kind of linguistic hormone that inhibited growth and development.

Nevertheless some words, purely scientific in their origins and fundamentally scientific in their meanings, sometimes acquire associations just in so far as they trespass across the intangible boundary between scientific and everyday speech. Two of the best examples of this are peroxide and atomic.

Hydrogen peroxide is a compound discovered by Thénard in 1818. It has a most interesting biochemical reaction with blood, which most chemistry books omit to mention, and is a strong oxidising agent. Hence it is a deodorant and bleaching agent, with a remarkably striking effect upon human hair. Some peculiar form of conservatism at one time caused many to look with distaste on the practice of bleaching the hair, and on the woman who did so, with the result that the word

peroxide in any non-chemical sense now bears a faint air of disapproval. Perhaps the most striking confirmation of this was seen a few years ago when a man, held on a criminal charge, was reported to have taken tea 'with a peroxide blonde' shortly before his arrest. Underlying this statement was the truly remarkable implication that the man's guilt might be assumed to be more probable because his hostess had fair hair.

So, too, atomic, as used to describe the atomic hypothesis or the atomic structure of matter, was until 1945 as emotionally neutral a word as pyroborate or hygrometric. But since the explosion at Hiroshima it has assumed a new implication, so that the common phrase 'this atomic age', which, taken literally, has no meaning at all, now holds a hint of menace, of terror and undreamed-of destruction. Quite recently the word atomic in a cross-word puzzle was the answer to the clue 'very powerful'. This may well have been meant to have been deliberately misleading, but even so the example, though trivial, is significant because it shows that in 1952 some people at least were supposed to associate atomic with powerfulness.

★ ★ ★

Among the many restraints, restrictions and prohibitions which characterise modern civilisation there is none that is concerned with the invention of words. Anyone may, apparently, invent and use any word with the same untrammelled freedom that children invent 'private' words in their nursery, and in doing so he is given no advice, little praise for a good word and little abuse for a

bad one. In consequence, bad words exist and are not rare in the language of science.

The commonest result of the habit of resorting to Latin and Greek for the components of new words is the frequency with which the two languages are used together, in the same word. Words like haemoglobin, from Greek haima, blood, and Latin globulus, a small sphere, and micronucleus, from Greek micron, small, and Latin nucleus, a nut, are examples. These words are called hybrids, and their appearance, their use and their persistence cannot be described as anything but lamentable.

Students of literary English are agreed in regarding these words as undesirable, yet they show an inconsistency, born no doubt of indifference, when they say that the requirements of science are so many and so intricate that a literary principle of this kind may be overlooked. There ought not to be any justification for relaxing a rule of language, even in difficult circumstances, and many thoughtlessly-made hybrids could easily have been avoided. Thus pentavalent may better be written as quinquevalent; and sometimes two possible improvements are available – for example, perivisceral can be replaced either by circumvisceral or perisplanchnic.

Avoidance of hybrids is not always as easy as this. The word arachnology derived from arachne, a spider, and logos, a discourse, literally means the study of spiders; it is often used in this sense and often used in the wider sense of the study of the Arachnida in general, that is to say, the study not only of spiders but also of scorpions, mites and other orders of the class Arachnida. For the study of spiders only the word araneology has

been suggested, in the interests of accuracy. But araneus is the Latin for a spider, so that the new term is hybrid, which ought never to have displaced arachnology. Clearly the name for the study of all the arachnids should be arachnidology, which is about as ugly a word as can be found. There is no word in classical Greek which refers to the larger group, for the ancient zoologists did not attempt to distinguish the orders, as we now call them: in consequence the choice must lie between using the ugly arachnidology or admitting the hybrid araneology. No doubt most zoologists, caring nothing for language or linguistic niceties, will use the latter, but the position remains unsatisfactory at best, evidence that we are living in an imperfect world.

3

THE GROWTH OF THE LANGUAGE OF SCIENCE

IN BRITAIN the language of science has been growing, at first slowly, then with ever-increasing speed, for more than five hundred years. In that time it has also continuously pushed its way further and further into the language of everyday life, so that there is a simultaneously lengthening list of words which, first introduced in the interests of scientific work, are now so generally used that few people would think of them as in any way scientific or specialised or unusual.

There are few surprises in the story of scientific writings than can equal the information that the English scientific vocabulary began with Geoffrey Chaucer. But so it is. In 1391 he produced, as he says, for 'litel Lowis my sone', a small book bearing the title *A Treatise on the Astrolabe*. It seems that Lewis Chaucer, of whom no more is known, showed an early bent towards science, to encourage which this book was written by his father. Moreover, he wrote it in 'naked wordes in English; for Latin ne canstow yit but smal, my lyte sone'. In this work he used words taken from other languages and explained their meanings for the benefit of his young reader: for example, he wrote 'tropik, of "tropos", that is to seyn "agaynward" ', and thereafter adopted such words as part of the vocabulary

of his subject. Thus the words latitude, longitude, meridian, declination, ecliptic, and zodiac are all used by him in their present senses; and this is also how the Arabic words azimuth, nadir and zenith first came to be included in the English language.

It was therefore Chaucer who, using such words as equator, equinox, horizon, degrees and minutes, first gave continuance to the practice of using, as scientific terms, words taken directly from Latin or Greek. He is thus the originator of the system described in the last chapter, and which is now a custom followed without question.

Chaucer, in fact, appears to have had a considerable knowledge of the science, or natural philosophy as it was then called, of his time. In the Prologue of *The Canterbury Tales* he could write such a couplet as:

Ther nas quicksilver, litarge ne brimston,
Boras, ceruce ne oille of tartare noon

Later, in the Canon's Yeoman's Tale, he describes an experiment conducted by an alchemist in terms which suggest personal acquaintance with the business. Some commentators have thought that the story is based on his own experience of having been deceived by an alchemist. Whether this is so or not, it is interesting to read such lines as:

As bole armoniak, verdegrees, boras 790

or

Arsenik, sal armoniak, and brimstoon 798

or

Sal tartare, alkaly and sal preparat

We are given an attractive picture of the laboratory set-up:

Sondry vessels maad of erthe and glas,
Our urinals and our descensories,
Violes, croslets and sublymatories,
cucurbites, and alembykes eck,
And othere swiche, dere y-nough a leek

(Urinals are test-tubes, croslets are crucibles, cucurbites are retorts: the last four words, dear enough at a leek or trifle, scornfully express Chaucer's estimate of the value of the whole.)

In other places in this tale we find references to

orpiment	vitriole
realgar	alum
unslekked lym	magnesia
sal peter	

This is of more than passing interest, for in Shakespeare, a hundred and fifty years later, we have evidence of knowledge of military and musical matters and even of law, but almost no interest in the science of his time. Shakespeare never referred to compounds as 'scientific' as litharge, cerussite or sal ammoniac, and even his references to minerals are usually metaphorical.

We leave the fifteenth century by making a short list of words that have at least a scientific flavour and which belong to what philologists call Middle English, 1150–1350, or Late Middle English, 1350–1450.

amber	iris	science
antimony	magnet	sciential
diastema	marcasite	semen
distil	nitre	thorax
duodenum	rheumatic	ventricle
hermaphrodite	sciatica	

SIXTEENTH CENTURY

In the sixteenth century the vocabulary of science grew but slowly; and the chief reason for this was the custom of writing all important works in Latin. It will be remembered that in 1544 Roger Ascham had lamented the fact that he had chosen to write his *Toxophilus* in English, saying that he would have preferred to have used Latin.

The century, however, also saw some, at least, of the writings of Sir Francis Bacon (1561–1626) who from the scientist's point of view is of greater philological interest and importance than Shakespeare. Bacon was the first to use the words acid and dissection in their modern senses. Dissection, indeed, gives the linguistic keynote of the century, the dominant feature of which was the appearance of a large number of words concerned with the human body.

The word skeleton, for example, which dates from 1578, is often assumed to mean a set of bones; but it is derived from skeletes, dried up, and its literal meaning is therefore concerned with desiccated remains rather than bones. Among the bones of the vertebrate body which were named during this century are:

astragalus	1541[1]	scapula	1578
cranium	1543	tibia	1548
femur	1563	ulna	1541
mandible	1548		

Among the softer organs, tissues and so on are to be found:

abdomen	1541	mesentery	1547
cartilage	1541	nectar	1555
cerebellum	1565	optic	1541
chorion	1545	pancreas	1578
chyle	1541	parietal	1506
colostrum	1577	periosteum	1597
cornea	1527	pus	1541
crural	1599	scrotum	1597
glottis	1578	tendon	1541
jejunum	1541	ureter	1578
jugular	1597	virus	1599
labium	1597	vulva	1548
larynx	1578		

At the same time, concern with the human body especially in sickness was absorbing more attention, and as a result a number of diseases were distinguished by name during this period.

catarrh	1533	hydrophobia	1547
epilepsy	1578	leprosy	1535

[1] The dates given to the words in this list, and in all similar lists in this chapter and elsewhere, are those of their first recorded appearance in English, and are taken from *The Oxford English Dictionary*. The words themselves have been chosen as being good examples of the century or the science under consideration – typical representatives which are also reasonably familiar.

mumps	1598	scurvy	1565
nephritis	1580	smallpox	1518
phthisis	1543		

The anatomists, however, if dominant, were not entirely alone in the field: a few examples may be given from other sciences.

CHEMISTRY		PHYSICS	
alloy	1595	parabola	1579
evaporate	1545	temperature	1531
soda	1558	vacuum	1550

BOTANY		ZOOLOGY	
alga	1551	giraffe	1594
genus	1551	mosquito	1583
species	1551	tarantula	1561

In the above lists there are nine words dated 1541. Except pus, all these are found in a translation by Robert Copland of Guydon's work entitled *Questyonary of Cyrurgyens* and provide a good example of the way in which, in those days, a single book might well bring several new words into the language simultaneously. There are also five words dated 1597. They have come from two translations, made by one A.M. and published in that year, of Gabelhauer's *Boock of Physike,* and Guillemeau's *French Chirurgerye.*

SEVENTEENTH CENTURY

Clearly, by the end of the sixteenth century science had begun to make an impression on the language, and a scientific vocabulary was beginning to take shape. By

the end of the seventeenth century British scientists could look back on a hundred years of astonishing progress, on a period that had witnessed the lives and works of William Harvey (1578–1657), Isaac Newton (1642–1727), Robert Hooke (1635–1703), and Robert Boyle (1627–91), as well as twice as many lesser names.

The linguistic influence of the first two of these great men was largely indirect, for their chief works were not written in English. Harvey's *De Motu Sanguinis* appeared in 1628, a book which, though physically describable as 'a wretchedly printed little Latin quarto of seventy-two pages' will always be one of the great classics of medicine. Newton's most famous work was published in 1687. Its full title was *Philosphiae Naturalis Principia Mathematica*, and very possibly it was the most famous scientific book of all time. But the use of Latin was not now universal. The Royal Society grew out of the Invisible College and received its charter in 1662; its *Transactions*, which have appeared without interruption ever since, used from the first to print contributions both in Latin and English. Moreover, even if science was read in Latin it was talked about, and often written about, in English, so that its new ideas had to be given expression in the spoken language. In consequence a very considerable number of scientific words date from the seventeenth century.

In the first group we must inevitably recognise the continuation of the study of the vertebrate body.

acromion	1615	anus	1658
allantois	1646	atlas	1699
amnion	1667	auricle	1653

axis	1694	olfactory	1658
calcar	1662	ophthalmic	1605
cardiac	1601	ovary	1658
carpus	1679	parturition	1646
carotid	1667	patella	1671
cerebrum	1615	pelvis	1615
cholagogue	1671	penis	1693
chyme	1607	peristalsis	1655
clavicle	1615	pharynx	1693
clitoris	1615	pineal	1681
coccyx	1615	placenta	1691
cochlea	1688	pleura	1664
coeliac	1662	pylorus	1615
coitus	1615	stapes	1670
cuticle	1615	sternum	1667
excretion	1605	tarsus	1676
flexor	1615	testis	1681
foramen	1671	thymus	1693
humerus	1666	tonsil	1601
ileum	1666	tragus	1693
ischium	1646	tricuspid	1670
incus	1669	tympanum	1619
lacteal	1633	urethra	1634
lanugo	1677	uterus	1615
malleus	1669	vagina	1682
maxilla	1676	vertebra	1615
mucus	1661	viscera	1651

A glance at the above list shows first that but few bones of the vertebrate skeleton remained unnamed by 1699, while more conspicuously the organs and process of reproduction have become almost completely describable

in the same words that are in use to-day. Eleven of these words form a group derived from Crooke's *The Body of Man*, published in 1615. Four others, bearing the date 1693, are found in Blancard's *Physical Dictionary*.

The rate at which diseases were named fell to about half its previous figure, and the following examples may be quoted:

rheumatism	1601	rabies	1661
pneumonia	1603	lumbago	1693
goitre	1625		

The succession of new names for old and new diseases may well be carried on at this point. The first feature seems to be a continued drop in the number of names, for the eighteenth century can apparently boast no more than four:

dyspepsia	1706	eczema	1753
malaria	1740	neurosis	1776

However, the nineteenth century shows a remarkable change and the following eighteen words may be quoted as illustrating it:

gastritis	1806	haemophilia	1854
pellagra	1811	leucaemia	1855
laryngitis	1822	neurasthenia	1856
neuralgia	1822	uraemia	1857
phlebitis	1822	diphtheria	1857
kleptomania	1830	aphasia	1867
cirrhosis	1839	agoraphobia	1873
neuritis	1840	claustrophobia	1879
mastitis	1842	beri beri	1879

The interesting feature of this list is the high proportion of nervous and mental troubles which it includes. Can it be that 'the pace of modern life' was beginning to make itself felt, even in times to which we are accustomed to look upon as quiet and prosperous? Were the so-called 'spacious days of Queen Victoria' really more cramped than we believe?

A philological feature of disease names is the frequent occurrence of the suffixes -osis and -itis. Both are of Greek origin. The former carried the implication of a condition or state of being, but not in any pathological sense. In the scientific vocabulary, apart from medicine, the most familiar example of the original use of the suffix is probably symbiosis (1877), the state of living together for mutual benefit, seen, for example, in the partnership of alga and fungus which produces a lichen. The doctors, however, have given it a secondary implication of disease or damage, as in tuberculosis.

Whereas -osis was, and is, a suffix of nouns, -itis was a suffix of adjectives. It is the feminine of -ites, meaning or implying an association with, as in the familiar Biblical verse 'the children of Israel dwelt among the Canaanites, Hittites and Amorites, and Perizzites and Hivites and Jebusites', *Judges, iii*, 5. It was at first used to precede the feminine noun nosos, disease, so that gastritis nosos meant disease of the stomach; but quickly the adjective shed its accompanying noun and stood by itself, as the name of the disturbance. For some reason it has a greater popular appeal than -osis, so that modern writers in a spirit of levity coin such words as examinationitis and skirtitis, to express an undue concern over a forthcoming examination or the wearer of a skirt.

There was in the seventeenth century a predominance of new medico-biological words, which at first sight seems to be rather surprising. Chemistry was well on the way to shaking itself free from the shackles of alchemy, as well as the mediaeval idea of the Spagyrists that all forms of matter were composed in varying proportions of sulphur and mercury. In this *The Skeptical Chymist* of Sir Robert Boyle played a conspicuous part; indeed it is to Boyle that we owe our present conception of the element as a substance that cannot be chemically decomposed, but the science as a whole was as yet too unformed to have found the need for a new vocabulary on any considerable scale.

Much the same is true of physics. Newton's work was an exposition of first principles: it laid foundations, but the bulk of the superstructure was to come. The result is that the lists of chemical and physical words belonging to the period do not approach the length of the anatomical list. The following are among the most interesting additions:

CHEMISTRY

acid	1626	laboratory	1605
alkahest	1641	potash	1648
apparatus	1628	stalactite	1677
calomel	1676	stalagmite	1681

PHYSICS

acoustic	1605	gravity	1641
atmosphere	1638	lens	1693
ductility	1654	meniscus	1693
equilibrium	1608	microscope	1656
focus	1644	pendulum	1660
fulcrum	1674		

In the realm of natural history there was more activity. The invention of the microscope (the word has just been listed as dating from 1656) had shown the way to new realms in which discoveries were plentiful. The writings of the seventeenth century naturalists, and of John Ray (1627–1705) in particular, were doing much to promote the spirit of scientific enquiry; in fact it is probably true to say that the biological sciences did more to establish the methods and principles of scientific investigation and advance, than did the physical sciences. Here is a sufficient list of examples:

acarus	1658	corolla	1671
alburnum	1664	environment	1603
amphibia	1609	lichen	1601
anastomosis	1615	parenchyma	1651
blatta	1601	pedicel	1676
cactus	1607	pedicle	1626
calyx	1693	pod	1688
cambium	1643	proboscis	1609
carnivorous	1646	stamen	1668
cassowary	1611	tuber	1668
cockroach	1624		

A corner of mathematics should also be mentioned as responsible for a few words which are now in very general use. To Sir John Napier (1550–1617), the inventor of logarithms, is due a large share of this advance.

formula	1638	logarithm	1615
hyperbola	1668	series	1611

Already, in this century, scholars were beginning to

take notice of the invasion of the mother tongue by the strange vocabulary of the scientists. The process of course was not new, but now, for the first time it became sufficiently noticeable to make both readers and writers wonder if it were altogether a desirable phenomenon. It inspired John Wilkins (1614–72) one of the founders of the Royal Society, to the writing of *An Essay towards a Real Character and a Philosophical Language*. The idea of a universal language which all learned men should use in their writings, and so leave the mother tongue unsullied by the barbarities of the scientists was no doubt a commendable one. But like many ideas of the same character it had no chance of general acceptance or of being put into practice.[1] The steady trickle of new scientific words continued, the time for diverting it into a channel of its own had passed – if indeed such an operation had ever been possible – and it was destined to grow and to go on growing.

In so doing it was bound to play an important part in that division of philology known as semantics, or the study of meaning. As a discovery becomes known or a new idea begins to secure acceptance it exerts a direct influence on the meanings and implications of the words in which it is described or expressed, and on related words. In the century just reviewed Newton had communicated the idea of universal gravitational attraction. Henceforward the word gravity had a new meaning, the implication of the word weight was made more exact,

[1] Wilkins was perhaps not so much concerned with the purity of literary English as in the creation of a language in which the words were so free from ambiguity that it would describe things and express thoughts with the perfect accuracy that science demanded. In this he had the practical support of the Royal Society.

and the new words gravitate and gravitation came into being. A little later the nature of light was, by general opinion, to be described as a vibratory disturbance of the ether, whereupon the word ether began to take on a new meaning and rapidly to lose its former one – the mythical atmosphere breathed by the gods.

Well-known examples of the same kind of change are to be seen in the meanings of the words machine, machinery and automatic, all of which were the result of the development of the idea of force. The original meaning of machine was a scheme, a plot or an intrigue, such as to-day appears in the rather ugly word machinations. It now began to be applied to a material device for changing the magnitude and direction of forces or forms of energy; and usurped for itself the adjective mechanic which was formerly descriptive of manual labour.

So too, automatic, derived from autos, self, was applied to any kind of movement which came from a cause within the moving object. Thus the beating of the heart and the peristalsis of the intestine, were automatic. From this the phrase automatic machines was meant to imply that the internal nature of the machine enabled it to perform its functions as if automatically, that is to say, it was a comparative, almost a metaphorical description; and finally, since a machine reacts unconsciously and always in the same way to the stimulus which sets it going, the adjective acquired its present meaning of unthinking – invariable.

EIGHTEENTH CENTURY

The story of the eighteenth century is, in broadest outline, an intensified version of that of its predecessor.

The flow of words applicable to the vertebrate body is, inevitably, drying up, as fewer parts remained to be described; the following, however, may be noted:

adductor	1746	fallopian	1706
adipose	1743	fibula	1706
caecum	1721	metacarpal	1739
calcaneum	1751	oviduct	1757
coracoid	1741	sacrum	1753
coxa	1706	thyroid	1726
cricoid	1746	xiphoid	1746
ethmoid	1741		

Pride of place was now taken by biology proper, for the description of species had begun to accelerate and with the increase in their numbers the necessity for a system of classification was becoming more intense. Further, biologists' opinions of the principles of classification were developing, following the example set by Linnaeus (1707–78). Among the new biological words of the eighteenth century are:

ZOOLOGY		BOTANY	
agouti	1731	anther	1791
albino	1777	apetalous	1706
anaesthesia	1731	capitulum	1721
analgesia	1706	corymb	1706
antiseptic	1751	dicotyledon	1727
aphis	1771	dioecious	1748
apterous	1775	drupe	1753
axolotl	1786	etiolate	1791
cachalot	1747	glume	1789
coleoptera	1763	monocotyledon	1727

elytron	1774	monoecious	1761
fauna	1771	nectary	1759
habitat	1796	petiole	1753
hermaphrodite	1727	pileus	1760
natterjack	1769	pistil	1718
nucleus	1704	plumule	1727
taenia	1706	testa	1796
termite	1781	volvox	1798

The chemical vocabulary reflects the great changes in belief that occurred during this century. The composition of air was established by Priestley, and as a result of his discovery of oxygen the phlogiston hypothesis ceased to be acceptable as an explanation of the phenomenon of combustion. A secondary result of '*la révolution chimique*' was an overhauling of the whole system of chemical nomenclature; and in consequence the list of new chemical words is of interest because its significance is disproportionately greater than its length. The list includes:

carbonate	1794	nitric	1794
carbonic	1791	oxygen	1790
cupric	1799	oxide	1790
ferric	1799	phlogiston	1733
hydrogen	1791	sulphate	1790
lactic	1790	sulphite	1790
molecule	1794	sulphuric	1790
nitrogen	1794	stannic	1790
nitrate	1794	uric	1797

Two of the above words form parts of two interesting triads:

ferreous	1646	cupreous	1666
ferrous	1765	cuprous	1669
ferric	1799	cupric	1799

It appears that the ordinary man, with no special interest in chemistry described iron or coppery things as ferreous or cupreous: the early chemists adopted the shorter form of ferrous and cuprous, and the contrast between these and the corresponding ferric and cupric had to wait until chemical nomenclature became systematic (see Chapter 4).

NINETEENTH CENTURY

Mr A. J. Lawrence has written: 'From the end of the eighteenth century the trickle of new scientific words became a steady stream, and by the end of the nineteenth it had swelled to a flood.' Moreover, the stream was by now almost wholly a stream that rose from the springs of far-off Athens and Rome. The borrowings and misusing of ordinary English words had disappeared, but the classical garb worn by the language of science, now in vigorous adolescence, did not earn the approval of the philologists and others of this time.

The effort of Wilkins two centuries earlier to direct the vocabulary of the scientists into channels of its own has already been mentioned: but now there arose a more voluble opposition, based on the complaint that the English dictionaries were becoming swollen with words that did not properly belong to this country. The creation of an international language for science would, it was felt, confine to their proper place 'these monstrosities of un-English English'.

There was never any doubt that the opponents of the new classically derived words, the Purists as they called themselves, were trying to control a flood that could not in fact be stemmed by any means, and for this there were several reasons.

In the first place the new words had all the intrinsic values of clear implication, precise meaning and freedom from distorting association which have already been mentioned. A word like geology for example was so clearly defined on the occasion of its first appearance that its meaning could never be in doubt; but if in its place the Anglo-Saxon earthlore were to be substituted, there would be an inevitable tendency to expand its meaning, and to use it in reference to things for which it had never been intended.

Secondly, the practice of composing new scientific words by compounding fragments of the native tongue was already being practised in Germany, and the results were not encouraging. The new and precise name oxygen was much better suited to a chemist's purpose than the German Sauerstoff, and appendicitis was preferable to such a word as Blinddarmentzündung. No normal Englishman would attempt to produce words of this kind from pieces of English, but suggestions or replacements of the words of science were freely forthcoming from William Morris, Francis Newman, Edward A. Freeman, and others. The most enthusiastic champion of Anglo-Saxonmania was the Dorset poet William Barnes (1806–86). Like many another he enjoyed playing with words, but he seriously believed that a general acceptance of his suggestions would make the understanding of science easier for the less educated.

The following examples are given as a reminder of what was scarcely more than an amusing phase:

sky-sill for horizon	fourwinkle for quadrangle
gleecraft for music	forstoneing for fossil
fireghost for electricity	folkwain for omnibus
deemstery for criticism	starlet for asterisk
hearsomeness for obedience	yeargyld for annuity

The philologist of today, reviewing the almost interminable list of words new in the nineteenth century quickly sees that a full treatment of them is impossible. Barfield has said that 'a list of words like anaesthesia, galvanometer and telephone, which appeared in the middle[1] of the nineteenth century, tell a full and fairly accurate story of its extraordinary sudden mechanical and scientific development, but such a list has yet to be compiled'. This was in 1926. To compile such a list as is here suggested is not impossible; for nothing more than industry and patience is needed to do it, but a moment's reflection shows that the perusal of such a list would be unutterably tedious to the reader. Nor would it serve any useful purpose beyond confirming what is already sufficiently obvious – that the scientific words of the century were very many. In the list of about four thousand dated scientific words that was made in the course of writing this book, nearly a thousand belonged to the nineteenth century.

It is more interesting to notice that borne along in the flood there is a small proportion of words which have shown themselves to be of wider usefulness and so may

[1] The first recorded appearances of these three words were in 1847, 1802 and 1876 respectively.

be found in the vocabulary of the ordinary man who uses them with no sensation that he is talking scientific jargon. Here are twenty examples, divided between the physical and the biological sciences:

PHYSICAL		BIOLOGICAL	
accumulator	1877	aspidistra	1822
barograph	1865	cereal	1828
centigrade	1812	chlorophyll	1819
colloid	1847	chromosome	1890
dynamo	1882	conifer	1851
gyroscope	1856	hibernate	1802
microtome	1856	metabolism	1878
oxidise	1802	pasteurise	1881
ozone	1840	protoplasm	1848
titrate	1870	spermatozoon	1836

But of course the greater number of this century's words have no value whatever in the common currency of conversation between ordinary men and women. Here are twelve words quickly selected, almost at random:

adiabatic	1877	lodicule	1864
allotropy	1849	micron	1892
catadromous	1881	neurilemma	1825
coleorhiza	1866	phylloclade	1858
conidium	1870	pygidium	1849
isomerism	1838	typhlosole	1859

which are all used commonly enough in the different sciences to which they belong, but which have no place outside the language of the laboratory. Their existence, and that of scores of others like them, is but evidence of the increasing degree of specialisation which was, and

is, the characteristic of the developing language of science. It would be intolerable to read a very long list of words like these, and quite purposeless.

TWENTIETH CENTURY

The new words that have arisen since the beginning of the twentieth century, provide I think, something of a contrast with those of the preceding century, in that a larger *proportion* of them are familiar outside the laboratory. Scientists had to a recognisable degree laid the foundations of their separate studies by 1901, so that the very great speed with which their vocabularies needed expansion has slackened since then. Moreover the public, which cared little for the fundamental principles of physics or botany or any other science as such, is now much more keenly alive to the effects which scientific advances may have on their individual lives. Any discovery that is not too remotely academic is likely to provoke interest and discussion, with a genuine, if sometimes misguided, attempt to grasp and to use the new words in which the novelties are described.

To give definite examples, the words photon and allergy may be chosen. The former, belonging to the science of optics, is one that finds no niche in the thoughts of the ordinary man and is never heard in his ordinary conversation. On the other hand, allergy, which may be defined as an abnormal and disproportionately intense reaction by the human body to stimuli from minute particles of substances which are harmless to the majority of persons, and of which hay-fever is the most familiar example, is a word which has captured the imagination of the plain man. He uses it, or its adjective

allergic, as if it meant no more than mere dislike, and may be heard to describe himself as being allergic to Mondays or allergic to embryology, when he only means that he does not appreciate these things.

Words like this, scientific in origin, narrowly specialised in their true meaning, yet familiar to a very large number of people who make no pretence of being scientists, can be seen to take a large share in the following list of two dozen words, all of them characteristic of the present age:

acidosis	1915	niton	1912
allergy	1913	penicillin	1929
behaviourism	1914	photon	1926
biochemistry	1902	positron	1934
cyclotron	1932	proton	1920
deuterium	1932	quantum	1910
gene	1909	radar	1942
holism	1926	secretin	1903
hormone	1902	stratosphere	1908
ionosphere	1932	thermite	1900
isotope	1913	troposphere	1914
millibar	1912	vitamin	1912

This list gives support to the opinion which, whether it be true or not is certainly the popular one, that science to-day is more concerned with the application of its latest discoveries than with the advancement of pure knowledge. The latter, as we shall see, is not easily comprehensible, but when it enables us to kill insect pests, to grow better crops, to replace silk and wool by glistening durable artificial fibres, to visit the moon, or even more hopefully to defend ourselves against

possible aggressions, then it presents a different sort of appeal. Unfortunately its language is largely expressed in vocalised initials, of which Anzac was perhaps the first example to become universally adopted and of which Uno, Unesco and Nato represent the descendants. Whether these creations are to be called words or not the future will decide: but they certainly belong to a different category from the words with which this chapter has been concerned.

A feature of the present century which cannot be ignored is the rapid multiplication of technical terms, consequences of the achievements of the technicians, applying the principles of science. Sufficient examples have already been given in this book to make it clear that new scientific words have usually been the inventions of the scientists who made the discoveries – Madame Curie discovered and named Polonium, Liebig discovered and named aldehyde, hygrotropism was the invention of the present writer, and so on. There has been nothing in the past to prevent anyone from inventing and using any word, philologically good or bad; and there is nothing compulsory or illegal to-day.

But a position has been reached in which some sort of guidance or control is necessary, or is at least extremely desirable, not from any widespread aesthetic or literary conscience, but simply because of the risk that the same word may be composed and suggested almost simultaneously by different writers, who would perhaps use it for quite different purposes. This would quickly produce a situation as confusing as that prevalent in biology, where almost every animal and plant has received a number of names, and synonymy runs riot.

In this matter a welcome lead has come from the British Standards Institution. This body does not, indeed, exercise authority or control over the form of new words, but it issues a large number of glossaries for various industries, and in all of these, technical words and phrases are given precise definitions. Work of this kind is invaluable and should be fully appreciated by technicians, scientists and philologists alike. As it becomes more widely recognised and supported it must result in the appearance of fewer fantastic words, fewer hybrids, fewer follies.

A similar concern with the language of scientists and technicians, but of a more academic character, is shown by the Presentation of Technical Information Discussion Group. The Group meets at approximately monthly intervals in University College, London, and considers a wide range of topics with the object of raising the general standard of exposition.

4

THE CHARACTER OF THE LANGUAGE OF SCIENCE

UNTIL now our concern has been with the words of science, treated separately as symbols and without consideration of their contributions to the sentences into which they can be made or the prose of which these sentences are the units. This must now be done.

It was shown that among the characteristics of the words of science were their constancy of meaning, their ugliness and their emotional neutrality. It might therefore be argued that the language of science must show the same qualities as its constituent words and must be unchanging, ugly, insensitive. This is true only within limits. There is a holism about language, an emergence of new qualities in the whole over and above the qualities of its components, which gives to a sentence something not found in its separate words, and to a page something not present in a single sentence.

The words which the scientist borrows, imports and invents are intended, like all the other words of all other men, both for the writer who uses them in composition, and for the reader to whom they supply the only means of ascertaining the scientist's thoughts. The two uses are complementary and are closely allied, but an attempt, perhaps artificial, will be made to separate them.

The successful composition of English prose is a

difficult art, which, like mathematics and sculpture, is more difficult for some men than for others. Fundamentally it involves a selecting of words, and secondarily it involves an arranging of words, and since there are nearly always alternatives both in choice and in pattern, it is very necessary that the writer should be clear about the reasons behind the final solutions of his problems.

The character of a sentence or a paragraph in English prose or verse arises from at least three different features of each separate word in it. Nearly forty years ago Mr John Bailey, in a study of Milton's poetry, determined that Milton used words which best provided him with three qualities: 'the exact expression of the meaning needed for the purpose in hand, the associations fittest to enhance or enrich that meaning, the rhythmical or musical effect required for the verse'. Although, as has already been pointed out, scientists do not write in the manner of Milton, the same attributes must be considered by every writer if he wishes to compose a satisfying sentence and one which is in harmony with the general effect that he is trying to produce.

Much might be said, and something must be said, about each of these qualities of a word. Reference has already been made to the fact that in ordinary speech a word may have more than one meaning, but it is also true that the same meaning may often be expressed by different words:

> I usually finished the work by twelve o'clock;
> I often completed the task by noon.

These two sentences have as nearly the same meaning as any pair which could easily be found. Yet in science,

just as one word has, or should have, one meaning only, so also there is usually only one word to express any particular meaning. Even so simple a statement as, 'total internal reflection occurs if the angle of incidence is greater than the critical angle', cannot, I think, be expressed in any other words, except, of course, by using absurd explanatory periphrases. Total internal reflection has no other name, nor have the angle of incidence and the critical angle. It follows that this statement, which incidentally expresses a fact of considerable importance, is likely to be made in the same words, whoever the author may be. He may be able to write our language with the incomparable skill of John Ruskin, or only with the moderate competence of a schoolboy; he is unlikely to cast the statement into any other form.

Writers about the English language often emphasise the fact that no two words have exactly the same meaning. Because of this much care is necessary in choosing the words which most closely express the exact shade of meaning which the writer wishes to convey, and the writing of clear, precise, unambiguous prose demands both care and practice. It appears that in this matter the scientific author is to be envied, for, provided that he knows what he wants to say, there should be few alternatives in his choosing of his words. Ideally there should be no alternatives, only one selection of words should be admissible. This would seem to suggest that the writing of scientific prose should be comparatively easy.

I think that it is a matter of experience that, in general, this is true; but it is true only in so far as one's paragraph is rigidly scientific. Here is an example:

> The prosoma of the Chelonethi is covered by a carapace, quadrate or triangular in shape, and almost certainly formed by a fusion of the primitive sclerites. Sometimes there are no transverse furrows, but often these are present, and divide the carapace into four regions. The first of these, anterior to the eyes, is known as the cucullus. It is morphologically the same as the usually perpendicular clypeus of Araneae and is probably homologous with the distinct hinged cucullus of the Ricinulei.

Such a paragraph is easy to write. I quote it from my own book *The Arachnida*, and therefore I know that, in fact, it was; and it is clear that this was so because the paragraph was rigidly scientific in the sense that it was intended for zoologists only. Hence no doubt arose in the mind of the writer that his readers would understand the meanings of such words as sclerites, cucullus and clypeus. To rewrite the paragraph so that it should be equally informative to an athlete, an archdeacon or an accountant would be difficult, and would take much time and thought – certainly far more than its effect on the minds of any of these readers would justify.

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But although this constancy of meaning among scientific words makes science comparatively easy to write, it also makes it dull, and the writer of scientific prose is condemned if not to dullness at least to being unoriginal. The sentence about total reflection, quoted above, is one example of this. Suppose, alternatively, that a chemist wishes to record the fact that when a solution of any chloride is added to a solution of a lead salt, lead chloride

is precipitated and can be purified by filtering, redissolving and crystallising. In this statement the words solution, precipitate, filter and crystallise cannot be displaced by any others; no other words have the same meanings. A well-known dictionary of English synonyms was found on consultation not to mention one of them, save only precipitate in its irrelevant sense as an adjective.

In consequence the scientific writer must abandon all hope of being interestingly original in style and can but cherish a faint hope that he may show some originality in the arrangement or treatment of his matter. Before he begins to write his book he must accept the fact that to a very large extent it is going to be just like all other books on the same subject.

The more elementary the book the more conspicuously will this be true. Prof. J. R. Partington has dealt with this fact in the preface to a book on elementary chemistry – and there are surely more introductions to chemistry more closely resembling each other than any other kind of scientific text. Admitting that he is about to deal with very familiar matters, he says that every author should be allowed his chance to find the ideal way of presenting them to the young student. He seeks justification in a parallel. Almost every novel, he says, deals with the same theme, but everyone agrees that successive generations of novelists should be allowed to treat it in the way that seems best to each separate author. But the two kinds of book are not exact parallels. The emotions that are occasioned by the meeting of a man and a woman may be described in a wide variety of words, and phrases can be attuned to varying intensities

with which these feelings exert themselves. This is not true of the preparation of nitric acid or the action of chlorine on caustic potash.

With this inevitable uniformity in his choice of words, the scientist is debarred, more by convention than necessity, from using any of the devices that lead to graciousness in writing. These devices, commonly called figures of speech, are the accepted ornaments of literary composition, and are wholly absent from scientific prose. The scientist does not write in metaphors; metonomy or satire might mar the clearness he prizes so highly; his facts do not lend themselves to arrangement in climax or bathos; he seldom allows himself even the indulgence of a mild alliteration. However amazing his phenomena may be, he never permits a hint of hyperbole. The action of a beakerful of hot nitric acid on half a pound of sugar is one of the fantastic sights in elementary chemistry and to watch it is an astonishing experience: I have known it to interrupt a nearby game of lawn-tennis, but I have never seen it described in a text-book in any words more exciting than 'a copious evolution of nitrogen peroxide'. Surely the scientist, besides being tone-deaf, lacks something that would testify to common humanity.

For again, the language of science makes no provision for the slightest gleam of humour. Perhaps this is inevitable, a consequence of the fact that science is really a serious business in which levity has no place. And yet very few departments of human thought can really be said to possess no openings at which cheerfulness may break in; so that the absence of humour from science must be due to its deliberate exclusion by the scientists

themselves. They work in an atmosphere in which determinism is the rule and surprises are the exception, and surprise more than anything else is the cause of the smiles that brighten the humdrum lives of men. It is necessary to search for a long time before one can find a passage in which a scientist has allowed himself to recognise a lighter side implied by the facts he is discussing, and the example given here should be regarded as a rarity and valued accordingly.

Dr A. R. Jackson, describing a collection of Arctic spiders in 1934, came upon a male Coryphoeolanus thulensis in which the palpal organ was fully extended, an unusual occurrence in preserved specimens. He suggested that this mild satyriasis might be due to the chance that the animal had been captured when close to a female or to the effect of the alcohol in which it had been preserved, and added the simple and not unnatural comment, 'women and wine, in fact'. The amount of critical correspondence which this called forth surprised both author and editor, and seemed to show that scientists are unduly sensitive to any suspicion of light-heartedness in serious journals.

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The sound of words is the origin of all the balance and rhythm of a sentence. A writer who wishes his sentences to possess these desirable qualities is helped by reading his sentences aloud; and if he is successful the result may be surprising in its unexpected attractiveness. Sometimes such sentences appear, as it were by chance, in the course of otherwise plain and unremarkable pages. I quote, as an example, from a recent novel:

> Lord Fingleton rode out to meet them in a flurry of golden retrievers, and they made a rakish cavalcade – the young horses, the excited dogs, the bouncing trap, the two large men and the girl in the silly hat.

A scientist very seldom tries to write like this, he is more likely to produce this:

> It has been shown that in electrolysis those metals whose use as cathode require the highest voltages in order to bring about liberation of hydrogen yield hydrogen of the greatest activity.

I picked this sentence quite by chance, opening a well-known chemistry text-book at random and reading the first sentence that caught my eye. I might, therefore, have found uglier ones with a little search; but here is a typical specimen which even carries the hall-mark of the careless writer, a grammatical mistake. 'Use' is the singular subject of the plural verb 'require'.

The sounds of words or sentences seem to make no appeal to the scientist. There are so many words in the vocabulary of science which are undeniably ugly that this must, in the main, be true; nor is it easy to recall an instance of a scientist's objection to a new word on the grounds that its ugliness would mar the acceptance of the principle which needed its use, or even that the reader's pleasure would suffer as he met it.

When it is realised that such words as onchosphere, siphonoglyph, telolethical and dozens and scores of others as cacophonous, and many that are worse, such as Anomomeristica and mitoschisis, have been proposed and used, it can only be imagined that

scientists are tone-deaf, and that they read silently without inward appreciation of the sounds of the printed words.

The point is one to which we shall return: for the present it seems that the care for sound which must be taken by any writer of literary English, and taken far more scrupulously by a poet, is simply not existent in the writing of science. The meaning is the only matter of importance.

Of course it is easy enough to show that in ordinary language the meaning of a word, impressed on us by long use, is of greater power than its actual sound. An excellent example of this is found in the story of the two cricketers who, in an attempt to improve the close understanding which existed between them and enabled them to steal many short runs, sought to confuse the fielding side by calling to each other 'No' with the implication 'Yes', and 'Yes' with the implication 'No'. They found that they so often reacted to the customary meanings, instead of listening to and interpreting the sounds, that they invariably ran one another out.

* * *

Discussion of the scientist's concern with the sound of his words has occupied less space than the discussion of his greater concern with their meanings, but his concern with their associations will occupy a little more. In ordinary speech the associations which a word acquires in the course of its life are of overwhelming importance and the choice of any particular word from among a number of alternatives is more strongly influenced by its associations than by anything else. So supreme is this

power that it can change the apparent meaning of a sentence – compare the words:

> Her boy has recently come into the house

with its almost exact paraphrase:

> Her son has just come home.

Again, association can supply an apparent meaning where otherwise there would be none. Shelley wrote:

> *The cloud which rested on that cone of flame was cloven. .*

and to a purely scientific reader the impression given by this sentence is that it is nonsense. He will argue that heat of combustion will so quickly evaporate drops of liquid that a cloud cannot rest on a flame; but for the poetically minded reader the associations of cloud, flame and cloven so thickly surround the words that their meanings do not have to be considered; an impression is produced, which is most likely to be the one which the poet sought to convey, and is almost certainly not that of impossibility which the scientist notices.

There are some words which have manifest associations in ordinary speech and which are often used by scientists. These words seem to shed their associations completely when they are found in a scientific environment. Examples are purity, truth and strength. Put them together into two sentences:

> The purity of her nature and the truth of her ideals gave her a strength that could not be mistaken.

> The purity of his reagents and the truth of his balance give him the strength of the solution without an error.

It can be seen that the three words concerned are used in the second sentence solely because of their meanings, and their associations have no influence on the impression which the statement produces.

Again, scientific words seem to have a property which inhibits the formation of associations. Words such as 'diathermanous' or 'anisotropic' repel associative accretions because they have no emotional content.

Further, any facet of human thought which might introduce an emotion can generally be expressed in the warmer tones of ordinary human speech, the use of which leaves the scientific terms in their untouched untouchable purity; just as the visitors who concentrate themselves about Broadway leave the rest of the Cotswolds to the enjoyment of others. For example, a physiologist may speak or write of the mammary glands of the female with a frigidity that is almost incredible to the lover who is thinking of the breasts of his mistress; and yet it is a fact that reference is being made by both to precisely the same objects.

This, then, is the position. The scientist is to be envied because he does not have to select his words from among groups of alternatives, and is then criticised because the sentences over which he can exercise so little control are not aesthetically pleasing to the ear of the reader. What can the scientist do? He can do very little, and his usual way out of the difficulty is not to recognise it, and to regard himself as immune from the problems which beset other writers. He uses the language of science according to his ability and is, or should be, grateful that its qualities make his task so easy.

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A language whose first qualities are precision and lucidity should be a language of great power, power not over men's hearts and emotions but over their minds and efforts. It should be the ideal language in which to explain abstruse concepts so that readers should have the least possible difficulty in grasping ideas that are strange to their accustomed modes of thought. In other words the language of science possesses great powers of penetration, carrying its readers to the core of a problem and, once there, expounding the difficulties encountered and to come. Generally it does this successfully and it is a fact that no scientific concept has ever been made easier to understand by attempts to express it in unscientific language.

Moreover, the scientist while writing science can write as he could never do in ordinary literary work, because he can use scientific and emotionally neutral words. The custom of writers, as of speakers, is to avoid direct statements of anything that has painful, fearful or shameful associations, and such ordinary biological events as death and reproduction are mentioned only in protective periphrases. The scientific writer has no need to use these methods; he can describe these happenings with outspoken plainness of speech because his scientific words are free from all misunderstanding, free from all the associations which have grown about Anglo-Saxon words with identical meanings. The language of science overturns the illogical attitude of the ordinary man, defies his spirit of taboo, permits no evasions and countenances no sniggerings. This conquest of the habitual mode of thought, if thought it be, of the average man is one of the

greatest triumphs that must be credited to the language of science.

* * *

When the language of science fails it does so not from its own weakness but because of the limitations of the mind of man. Many of the ideas of the scientists are far from being simple ones, and words, even the special words of the scientists' vocabulary, cannot express them shortly. Long phrases clog the mind, which in consequence can but imperfectly develop ideas which trail so much verbiage behind them. As an example of this one may quote the statement: 'If there are more cows in the world than there are hairs in the tail of any one cow, there must be some cows with the same number of hairs in their tails.' This fact is undoubtedly true, but when it is presented in a form which necessitates thirty-three words and even when the important ones are short homely words like cow, hair and tail, the mind of the reader fails to penetrate immediately to the central facts. He may ask for time to think it over, or even for a careful explanation, taken slowly, step by step, until at last the light breaks through and the principle is accepted as obvious.

But if this is the reception given to relatively simple statements, what can be expected of more complex ones? Obviously they will be so cumbersome as to be quite unwieldy. The only hope of progress is to replace the wordy phrases by something that can be more easily manipulated, to have a symbol instead of a mass of words. Thus even a child soon learns to begin the solving of an algebraic problem by suggesting that,

shall we say, the speed of the cyclist in miles per hour on his outward journey shall be shortened to the single symbol 'x'. A simplification like this makes the problem much easier; the mind can do things with 'x' which it cannot do with the words 'the outward speed of the cyclist'. In fact, for purposes of investigation symbols are often better than words.

The comparison between the symbolic words of science and the symbols of the mathematician has been made before, and has been mentioned above, in connection with individual words. The symbolic language written by the mathematician has certain characteristics which it is helpful to investigate. First of all it has, like other languages, to be learnt before it can be used; a young student, at what is to-day called the Ordinary Level, is expected to be able to show that he has begun to learn it. He may be asked to express in symbolic form some such statement as: 'Twice the product of any two consecutive numbers is less by unity than the sum of their squares.' When he does so, and writes

$$2x(x + 1) = x^2 + (x + 1)^2 - 1$$

he is, in effect, translating the statement from English words into algebraic symbols, just as if he were translating it into French, or any other language. There is, in fact, an algebraic language, the chief characteristics of which are its brevity and its many possible applications.

The use of symbols, or the habit of making use of symbolic statement of facts, is an essential part of the scientific language. It reaches its highest development in mathematical physics. In this realm of science symbols first displace words, then render the words unnecessary

or forgettable, and finally surpass them. In the very simple example about consecutive numbers which has just been given, symbols displace the words, or, as we said, translate them. Still within the limits of elementary knowledge, a familiar formula like $\sin (A + B) = \sin A \cos B + \cos A \sin B$ can be used without the smallest need to think of the words in which sines and cosines are defined. If one tried to explain the meaning behind a symbolic statement of this kind to an intelligent adult who had never read enough mathematics to know what a sine or a cosine was, one would be amazed at the very large number of words that would be needed, and one would perceive how far a symbolic statement may be removed from its original ideas.

There is in consequence little reason to be surprised when it is detected that in the hands of a genius the manipulation of symbols may carry the manipulator beyond the realms in which the implications of the formula he has deduced can be expressed in words. Many of the formulæ derived and used in the theory of relativity are of this ultra-translatable type; and so justify conclusively the contention that symbolic expression is an integral part of the language of science.

In the language of chemistry formulae are indispensable, for their short symbols include so much information. If, for example, one can imagine a chemist who had not previously heard the word aniline, the name would tell him nothing about the compound in question (unless his Arabic were good enough to suggest its origin in indigo). But the formula $C_6H_5NH_2$ would tell him the elements of which it was composed, carbon, hydrogen, nitrogen, the proportions in which they

were present, 72 : 7 : 14, and would also enable him to foretell several of its reactions with other substances. In the same way a simple equation like $CuSO_4 + BaCl_2 = BaSO_4 + CuCl_2$ contains so much information about atoms, radicles and molecules, about the composition of the compounds concerned, and about the quantities in which they react or are produced, that to set it all out in full would take twelve or fifteen lines of print.

Moreover, such equations as the chemist writes are not only condensed forms of statements of chemical events. They are as useful and as indispensable as the symbols of the mathematicians. You, for example, may have bought a hundredweight of quicklime, and before it can be used in the garden, it must be changed into slaked lime by the addition of water. But how much water? Too little will not break up the rock-hard lumps, too much will produce a sloppy paste or cream, difficult to scatter. A chemist can answer your question. He writes the equation for the reaction, puts down the atomic weights of calcium, oxygen and hydrogen, and adds them up to get molecular weights.

Equation	CaO +	H_2O =	$Ca(OH)_2$
Atomic weights	$40 + 16$	$2 + 16$	$40 + 2(16 + 1)$
Molecular weights	56	18	74

These show that fifty-six parts by weight of quicklime react with eighteen parts of water. Hence your hundredweight of quicklime will require thirty-six pounds of water, or a trifle over three and a half gallons.

This is a childishly simple example which a chemist would in fact do in his head without writing anything on

paper; it has been introduced because it shows that, apart from practical trial and error, the problem could not be solved without the use of symbolic statement; and this again shows that symbolic writing is a part of the language of science.

* * *

It should be added, for the sake of completeness, that symbols are written occasionally by botanists and zoologists. The symbols,

$$\text{☿} \oplus K\,(5)\ \overparen{C(5)\ A\ O} + 5\ \underline{G}\,(5)$$

constitute the floral formula of the primrose, and to a botanist they imply that the primrose flower is hermaphrodite and radially symmetrical, with a calyx of five united sepals and a corolla of five united petals to which the five stamens are attached, and with a pistil of five united carpels, the ovaries of which are higher than the level of insertion of the petals. Floral formulae have no quantitative significance in a science which is more observational than metrical, but clearly they save space, and when the floral formula of, say, the evening primrose is written also,

$$\text{☿} \oplus K\,4\,C\,4\,A\,4 + 4\ \overline{G}\,(4)$$

the two flowers which happen to bear similar common names are very easily compared and the exact differences between them are concisely expressed.

In zoology formulae are rare, but

$$\frac{I\,3,\ C\,1,\ P\,4,\ M\,3}{I\,3,\ C\,1,\ P\,4,\ M\,3} = 44$$

tells a zoologist quite a lot about the teeth of a pig. This interpolation of biological formulae only serves to emphasise again the fact that symbolic writing is a characteristic of the language of science.

* * *

The general impression made by this attempt to describe the language which scientists use is, inevitably, that it is a language which clearly reflects the attributes of scientific knowledge. In recognition of this fact Dr Whewell wrote: 'When our knowledge becomes perfectly exact and purely intellectual, we require a language which shall also be exact and intellectual; we shall exclude alike vagueness and fancy, imperfection and superfluity; in which each term shall convey a meaning steadily fixed and rigorously limited. Such is the language of science.'

The scientist, however, is not to be allowed to derive any feeling of complacency from these words. Another appraisal of the language of science, describing it in essentially similar terms and praising it for its 'continuous clarity' has called forth criticism from a well-known authority on the English language. He takes the point of view that there is much besides science in the world, and that men 'better qualified to speak of the intangibles, the imponderables and the ultimates than are the scientists certainly do not think this somewhat standardised, merely efficient writing to be the best. Efficiency and lucidity are two great virtues in writing, but they are far from being the only virtues'.

Only to a very superficial view can such a criticism appear to be justified, and it cannot be allowed to remain

unanswered. The critic is, in fact, complaining that scientific writing is not something that it never intended to be and that it never should be. As well might a spider be criticised for secreting silk instead of milk.

The whole of this chapter may perhaps be summarised by saying quite shortly that the writer of the language of science must from the outset abandon all thoughts or hopes of achieving eloquence; that is to say he can scarcely attain that appeal to the emotions which is the ambition of the orator. But in the sense of fitness for his purpose, the sense that is to say, expounded by Cicero in the paragraph quoted in Chapter 1, the scientist should have the power to achieve distinction. He runs a much smaller risk of using the wrong word.

Accepting this possibility of an unemotional eloquence based on an exact fitness of words, we should therefore say, perhaps, that the scientist cannot write what in other kinds of literature is sometimes known as the 'purple passage'. Scientific exerpts do not often find places in anthologies of prose, unless these anthologies have been compiled not for their literary but for their scientific interest. In the latter case they cannot be read for pleasure, but only because they illustrate the development of scientific thought.

Finally, let me quote a short passage from the biological works of Professors Geddes and Thompson, which can lay claim to eloquence; it was written during a brief period of hope that science might be able to do something to alleviate the disillusion that followed the First World War.

> And as the psychologists are now bringing their own organ-building into fuller adjustment with that of biology, new voluntaries increasingly appear until even in the more idealist of these we may hear anew the vox Coelestis jubilate, however may, in these sad days, the vox humana wail.

My purpose in quoting it is to point out that its claim to notice rests on its use of a musical metaphor, and not on its science.

5

THE NATURE OF SCIENTIFIC PROSE

IN THE preceding chapter an attempt was made to appraise the language of science from the inside, that is to say, to examine it from the point of view of the scientist who has to write it. Our task is now to turn from the concave to the accompanying convex and to look upon the language of science from the outside, from the point of view of the student who has to read it.

There can be no doubt that to many readers the outstanding characteristic of scientific prose seems to be its incomprehensibility, nor can its most ardent admirers deny that it may appear to have a real tendency towards obscurity.

Dr Victor Grove, in *The Language Bar*, devotes a chapter to 'Language and Science' which is almost wholly concerned with the difficulty confronting the reader who wishes to find out what the scientists have to say. He quotes a sentence 'from a scientific journal' which I venture to requote here because it shows so well his point of view, and it also serves my own purpose:

> Begoniaccae, by their anthero-connectival fabric, indicate a close relationship with anonaceo-hydro-charideo-nymphaeoid forms, an affinity confirmed by the serpentarioid flexuosonodulous stem, the lirioden-

> droid stipules, and cissoid and victorioid foliage of a certain Begonia, and if considered hypogynous, would, in their triquetrous capsule, alate seed, apetalism and tufted stamination, represent the floral fabric of Nepenthes, itself of aristolochioid affinity, while, by its pitchered leaves, directly belonging to Sarracenias and Dionaceas.

Obviously, there is no doubt that much of this is incomprehensible to anyone but a botanist, and yet to a reader with even a modest knowledge of biology it does not seem to be so hopelessly obscure. This is because he is to some extent familiar with the botanist's words, and even more because he is familiar with the botanist's mode of thought. If, therefore, a biologist is reading Dr Grove's chapter, this example is a bad one for him. Let him therefore be given another. In *Nature* in December 1950 there occurred the following:

> If the Barclay-Butler rule be assumed valid over the entire absorption process, a knowledge of the differential heat of absorption will permit the interpolation of the excess entropy term from the Barclay-Butler line. A comparison of this term with the experimental entropy would give a measure of the configurational entropy as a function of the amount absorbed. This has been applied to some results of Crawford and Tomkins: the configurational entropy corresponds closely to that calculated for an ideal localised monolayer up to about half-coverage, after which a sudden inflexion marks the beginning of a steep rise in partial molar configurational entropy.

I think it is safe to suggest, without fear of contradiction, that the reader who has obtained some knowledge of the Begoniaceae from our first exerpt is unlikely to appreciate to the full the relations between excess, experimental and configurational entropy as outlined in our second: and vice versa.

Before we leave these two passages, it is of interest to compare them with a third quotation, as follows:

> According to Strabismus, Jupiter's hump is a negative result of solar radiation, as when atmospheric absorption reaches the equatorial zone of the planet during a maximum period of rotation the albedo (at 0·44) reflects a mean density, on the outer edges, of at least 62·71. In plain language this means that the zero meridian varies with the vapour-drift from the faculae, as in the comostatic water-cells of the nebulae of smaller planets.

There will be many readers to whom this extract is closely comparable to those given above, dealing with Begoniaceae and entropy; it will seem to be just another of the things that the scientists say, and which have, so often, no appreciable effect on the business of living. But it is, of course, only a piece of mock-science, in the characteristic style of 'Beachcomber', who succeeds so well in this type of humour, and it was printed not in a scientific journal but in the *Sunday Express* in August 1952.

The introduction of this third example is not entirely pointless. There have been philosophers who have freely admitted that there are parts of their philosophies which to some readers must appear to be perilously close to

nonsense; and it is equally true that some passages of scientific prose tend to assume very much the same appearance. It is, in fact, quite a common experience in the reading of contemporary science to think that it all really sounds as if the writer were trying to be funny.

The popular belief that all scientific writing is essentially obscure can be tested by turning for a moment from science to literature. The following passage was written by John Milton, a poet not usually described as obscure, and contained in a poem which is commonly supposed to be appreciated by all readers of English literature. Satan looks at:

His legions – Angel Forms, who lay entranced
Thick as autumnal leaves that strow the brooks
In Vallombrosa, where the Etrurian shades
High over-arched embower; or scattered sedge
Afloat, when with fierce winds Orion armed
Hath vexed the Red-Sea coast, whose waves o'erthrew
Busiris and his Memphian chivalry,
While with perfidious hatred they pursued
The sojourners in Goshen, who beheld
From the safe shore their floating carcases
And broken chariot-wheels

PARADISE LOST, i, 301–11

Here, within the space of seven lines of blank verse, an uninformed reader needs answers to nine questions:

1. Where is Vallombrosa?
2. What are Etrurian shades?
3. What is the relevance of sedge to the Red Sea?
4. Why is Orion described as armed?

5. What relation has Orion to storms in the Red Sea?
6. Who was Busiris?
7. Why are the Egyptians called Memphians?
8. Why is their hatred described as perfidious?
9. Why are the Israelites called sojourners in Goshen?

Few scientific writers are as obscure as this, demanding of their readers that they call up their general knowledge from a wide area of learning in order to appreciate their similies and allusions. The quotation from Milton demonstrates the necessity for some knowledge, which will help the reader to meet the writer half way. This is true of *all* reading, and of *all* writing.

Similarly, the two scientific paragraphs expose at once the character of the 'incomprehensibility' of which the scientist is accused. It is clearly no more than the consequence of the specialised kind of work which a scientist does. His account of it is unintelligible exactly to the extent to which it is specialised; the two qualities are directly proportional to each other. Very elementary science, such as is written in books for the young, can be understood by anyone; the text books of an undergraduate reading for the Natural Sciences Tripos are not very clear to his friends who may be taking theology, law or classics; while any scientist who tries to read *Nature* to-day is soon made aware of the difficulty of understanding other men's science.

* * *

The foregoing example is a particularly good one, for it may be used to show quite clearly that the incompre-

hensibility has grown with the rapid development of science during recent years. Forty years ago a schoolboy of sixteen, on the threshold of a scientific career, was encouraged to make acquaintance with contemporary knowledge and found that much of it was within his compass; to-day the same scientist finds that *Nature*, which he has been reading regularly ever since, is so abstruse that it is more from habit than from anything else that he pores over its puzzling pages.

Nor is it only science that is obscure because it is specialised. In a war-time sketch in *Punch* two young airmen were comparing experiences, and their grandmother, knitting and listening, confessed that she could not understand what they were saying. A moment later they were looking at the printed directions which guided and changed her stitches: and 'How wonderful, Granny,' they said, 'to be able to understand that.'

It may therefore be taken as proved that scientific writing is not inherently or necessarily obscure. To the readers for whom it is intended it is clear and unambiguous. There was a time in the history of diplomacy when any written message was safe enough from those who were not intended to know its purport, so rare was the ability to read; to-day similar messages need to be elaborately enciphered. If ever scientific education were to become as general as the ability to read, science would lose a very large fraction of its supposed unintelligibility.

Even with the present distribution of scientific learning, support can be found for the opinion that scientific writing, is, for those to whom it is addressed, not unintelligible but, on the contrary quite unusually clear.

This is an obvious consequence of the character, already mentioned, of the words of science, with their precise and unchanging meanings and their lack of misleading or distorting associations. It has been said, with some degree of justification, that in a sense 'we are all scientists now', and in the best scientific prose the best scientists are addressing one another. Because the present is the age of the specialist, the best scientists are almost invariably specialists in a limited area of learning, chosen by themselves, and it is as such that their prose should be considered. This consideration reveals the fact that the specialist who reads the works of his fellows has seldom any complaint about the clearness of their pages. He may disagree with them, be irritated by them, be inclined to reject the conclusions they contain; but it is a fact that very seldom are his criticisms based on a misunderstanding of the ideas expressed.

Surprised readers of this description of scientific prose as essentially clear, and not as essentially incomprehensible, may perhaps retort that the last paragraph has specifically mentioned the best scientific prose, and that in consequence the claim to inherent clarity must fail simply because the best prose of any category, scientific, solemn or sporting, will necessarily be clear to its readers, clearness being the fundamental requisite of all prose. There is, none the less, a fallacy in this criticism. Science text-books are only exceptionally written in prose of the highest quality, and more often they are written in prose that may be described in contrary terms, yet the students who use these books do not in fact find them difficult to understand. They may be strange, because they deal with unfamiliar matters; they may be

voluminous, making great demands on the memory; but they are not as obscure, even to the inexperienced reader, as the so-called average man is often led to believe.

★ ★ ★

A third characteristic of scientific prose, and one that is much more likely to be admitted by the ordinary reader, is its coldness. Never, in normal circumstances, does it show a glimmer of feeling or of warmth; it expounds and explains without emotion, so that one can read, as one has read, many pages of scientific books with never a quickening of the pulse. Of course this is a consequence of the fact that the words of science, without the associations that everyday words acquire, can produce only informative, symbolic writing. A scientific paragraph says precisely what it means, and no more; it reads as if it had been composed by a robot, with oil for blood and cogs for corpuscles.

The following example of a typical scientific passage, the opening sentences of Prof. J. J. Thomson's *Conduction of Electricity through gases*, will confirm this opinion:

> A gas in the normal state conducts electricity to a slight, but only to a very slight, extent, however small the electric force acting on the gas may be. So small, however, is the conductivity of a gas when in this state, and so difficult is it to eliminate spurious effects, that there have been several changes of opinion among the physicists as to the cause of the leakage of electricity which undoubtedly occurs when a charged body is surrounded by gas. . . . Quite recently it has been shown that there is a true leak through the gas

> which is not due to the dust or moisture the gas may happen to contain.

No reader would be likely to guess that this was introducing him to a work from which has sprung our now considerable and formidable knowledge of the atom.

As a contrast, a different kind of passage may be discussed. There is a curious group of desert animals known as wind-scorpions, counted among the most formidably-armed of all predatory creatures since their powerful jaws are in some species as long as the rest of their bodies. The following paragraph has been written about them:

> The fierce rays of the tropical sun have scorched the sands of the desert and night has fallen before the Wind Scorpion ventures out upon the chase. Armed more powerfully than any other creature, he stands for speed, for fury, for sudden death, while the Sable Goddess so cloaks his crimes that men know not his ways nor tell of his deeds. Mysterious in life, and no less mysterious in death, we look upon his hairy body, wondering what messages those spines convey, and what kind of existence is that in which every event is a vibration, every sensation is a touch.

Clearly the writer has made an attempt, not altogether unsuccessfully, to impart a little feeling into an account which to some extent paints a picture of the wind-scorpion's nature, rather than to write a precise account of its biology. The impression which this paragraph leaves in the mind of the reader is that although it makes some sort of appeal, it would be intolerable to have a whole biology book written like that.

Subjects which can be fitly described in emotive language can always be described in verse. An example may be given, to demonstrate the effect produced when this is done. The subject is the preparation of meta-dinitrobenzene:

Of nytrobenzene liquid some ten grains
Is added to, say, fortie grains (with care)
Of nytric and sulfuric acids mixed.
The whole is heated on ye waterbath
That boyls with freedom for an hour or more
Until a portion thence withdrawn and dropt
Into a bowl of water solid is.
(Beware! this operacion should be done
Or out of doors or underneath a hood!)
Ye yellow stuff is not yfiltered off
From supernatant liquid at ye pump
Washed with cold water then dried upon
A clean and porous plate of porcelaine.
A mixture this of three isomeric
Dynytrocompounds, and from this one may
The meta (one, three) compound isolate
By crystalising from warm alcohol.

It is quite obvious that to a modern reader this appears to be a joke, a joke of the type that is founded on incongruity or inappropriateness, like an account of Anthony ringing up Cleopatra on the telephone. Verse, like the specimen given above, suggests emotion in a topic which neither evokes nor permits any sentiment; hence we are justified in our assumption that if scientific prose is appropriate it is also cold.

* * *

For science is nothing if it is not metrical, its main concern is with the scale, the pointer-reading and the clock, and such entities as affection, goodness and beauty are of necessity neglected by scientists and find no place in their works. Indeed not only are these topics not discussed, they do not get even a passing mention. Flowers are among the most beautiful objects that nature produces, and existence in commercialised cities (which, for want of a better word, we call life) causes flowers to command a high price: an organised trade controls their distribution, and the whole of this depends on the beauty of flowers and their aesthetic effect. Yet no authoritative botanical work with which I am acquainted mentions their most conspicuous characteristic. Flowers are fully described as things of a certain structure and a certain function, but no hint is ever dropped that flowers have inspired our poets and invariably occupy prominent places at our own most emotional ceremonies, our weddings and our funerals.

The same coldly scientific treatment is found in zoology. One of the features of the frog, which was pointed out to me at Cambridge by a professor to whom I have ever since been grateful for so doing, is the astonishing beauty of its eyes – limpid, gold and brown, and lustrous. Yet of course, this surprising detail is never mentioned in the text books. Annually I pass on the professor's words to my own pupils and point out that Solomon could have justified our belief in his wisdom if he had addressed the Shulamite with the words 'Behold, thou art fair, my love; thou hast frog's eyes.'

If this is true of the more human sciences that deal

with living things, not much can be expected of the physical sciences. Lead iodide is easily precipitated from a solution of lead salt, redissolved in boiling water, and allowed to crystallise on cooling; if these crystals are seen as they fall through the liquid in the rays of the sun, they are objects of entrancing beauty. Or again, tiny crystals of silver precipitated by zinc and observed under the microscope, reflect the light and glitter in a way unsurpassed by a trayful of diamonds; but no chemistry book suggests that either of these substances should be seen like this

Many men and women, since the waters of the deluge disappeared from the face of the earth, have looked at rainbows and have described them in many phrases, evoked by a sense of beauty and wonderment. These sensations are not noticeable when the physicist says, '. . . the observer stands with his back to the sun, and all raindrops at about 42° to the line joining the sun to his head appear red and those at about 40° appear violet. These form the primary bow. For the secondary bow the angular radius of the red is about 51° and of the blue 54·5°.' No doubt this is an accurate statement of the principles underlying the formation of the rainbow, but it is hard to avoid the impression that something, something that appealed to Noah, is missing.

The geologists may, I think, reasonably claim some degree of exemption from these strictures. They have obviously recognised the beauty of the scenery of this country and have been able to expound a relationship between the nature of the landscape and the nature of the rocks beneath it. The opinion formed by the appreciative traveller is brought into a direct relation with

the observations of the examining geologist. Sir John Marr, in his well-known *Scientific Study of Scenery* was among the pioneers of this commendably human aspect of science. More recently Prof. J. A. Steers has given us a wonderful monograph on the coasts of Britain, and one scarcely knows whether it is a compliment to geology or not that his fine collection of illustrative photographs was later published apart from the scientific text, purely as a picture book.

The subject of a scientist's appreciation of beauty, is, I think, best summarised in the words of Prof. A. R. Michelson, who having seen in the course of his own researches some of the most astonishing colour-effects that light can be made to produce, wrote:

> These beauties of form and colour, so constantly recurring in the varied phenomena of refraction, diffraction and interference, are, however, only incidentals; and, though a never failing source of aesthetic delight, must be resolutely ignored if we would perceive the still higher beauties which appeal to the mind, not directly through the senses, but through the reasoning faculty.

Here speaks the authentic voice of science; an apotheosis of reason so intense that its satisfaction must transcend all the appreciations of sensuous impression. The scientist may not be emotional, may not be eloquent, but assuredly he knows that he must love the highest when he sees it.

* * *

Prose that is but partially intelligible to all but the specialists for whom it is chiefly intended and to whom

it is nevertheless unmistakably clear, prose that is cold, humourless and unemotional, this is surely a prose of marked individuality. If so, it must possess other features, possibly as unexpected as the lucidity which, after a rather unpromising start, was unearthed and vindicated.

Scientific prose has in fact a valuable and a not uninteresting characteristic – almost alone among all the different categories of prose it can be translated into languages other than the language in which it was first written, not merely satisfactorily but perfectly. This is of such interest to anyone concerned with language that it deserves further consideration.

Translation is an art about which much has been written and about which agreement is hard to obtain. Yet it must be remembered that most of the difficulties which provoke differences of opinion occur in the translation of literary masterpieces, and are based on the different interpretation of the translator's purpose. Is a translator to aim at putting the meaning, the sense of his author into a different language; or is he also to try to produce a reflection of his author's style, with a hint, or more, of his rhythms? There are those who support either alternative, and those who give them different emphasis.

It is fascinating to glance at a few attempts to solve this problem.

Vergil's opening to the Aeneid was:

Arma virumque cano, Trojae qui primus ab oris
Italiam fato profugus Lavinaque venit
Littora.

J. W. Mackail put it:

I sing of arms and the man who of old from the
coasts of Troy came, an exile of fate, to Italy
and the shore of Lavinium.

John Dryden wrote:

Arms and the man I sing, who forced by fate
And haughty Juno's unrelenting hate
Expelled and exiled left the Trojan shore.

William Morris's version was:

I sing of arms, I sing of him, who from the Trojan land
Thrust forth by Fate, to Italy and that Lavinian strand
First came.

C. Day Lewis's recently broadcast translation begins:

I tell about war and the hero who first from Troy's frontier,
Displaced by destiny, came to the Lavinian shores,
To Italy.

A scientist might write:

I tell of arms and the man who, driven by fate from the
coast of Troy, came first to Italy and the Lavinian shore.

These renderings of Vergil's lines are all noticeably different from one another. They differ because they were written at different times, by men who held different opinions as to the metre by which they could best convey the spirit in which Vergil wrote and which would most nearly bring an English reader into the same state of mind as an ancient Roman. The choice between such alternatives as blank verse, consisting

essentially of iambic pentameters, and rhymed couplets or heroic verse, would depend in part on the influence these verse-forms had on the translator himself and partly on their general popularity at the time. There would also be the choice between the disciplined regularity of classicism and the greater freedom of longer, looser lines and the even greater flexibility of prose.

This chapter is not the place for even a short discussion of the insoluble problems of literary translation, about which more competent authors have already written a great deal. This example was introduced because it shows that in translating two of the most familiar lines in Latin much diversity may be expected and many versions are possible; and this is in striking contrast to the translation of science, where there is less room for variation and far less for individual opinion. It is invariably true that two men translating the same passage from scientific French or German produce versions which are closely similar.

★ ★ ★

The most important quality in a scientific translation is no more than that the clearness of the original should shine with equal clearness in the translation. To achieve this, the choice and arrangement of words may wholly conceal all the literary powers of the first author and alter his style beyond recognition, but the benefit to the scientific reader will justify this. Indeed the principle on which the scientific translator should work, and the ideal he should hold before himself, should be a complete lack of evidence that his version is a translation at all, or, to

put it another way, it should not be possible from a comparison of the two versions to determine which was the original and which the translation.

It is obvious that no translator of Horace's *Odes* or of Homer's *Odyssey* would adopt such a principle; but I believe that it is what a scientific translator should attempt. Can it be done? In the accompanying examples the extent to which it can be achieved may be judged.

The French version was published in 1937, the English translation in 1939.

> Chez plusieurs animaux le rapport entre les mues et la croissance prend une forme mathématique intéressante. Chez les arthropodes la croissance linéaire entre les mues est gênée par l'enveloppe chitineuse rigide alors que l'augmentation de poids continue à se faire. Au moment des mues, l'organisme se débarrasse de la trop étroite enveloppe, une autre plus conforme à son poinds la remplace, et l'animal s'adapte rapidement au nouveau régime. Przibram et Mégusar ont admis que le poids des arthropodes devait doubler d'une mue à l'autre, ce qui correspondrait au dédoublement de toutes les cellules du corps. Par conséquent, les dimensions linéaires devraient s'accroître d'une mue à l'autre à raison de $\sqrt[3]{2} = 1{\cdot}26$.

> In many animals the relation between moulting and growing takes an interesting mathematical form. Among arthropods linear growth between moults is prevented by the rigid chitinous skeleton, while increase in weight continues to occur. At ecdysis the animal rids itself of its tight skin, another more

suited to its weight replaces it, and the animal quickly adapts itself to the new régime. Przibram and Mégusar supposed that the weight of an arthropod should be doubled between one moult and the next which would correspond to a doubling of every cell in the body. In consequence linear dimensions should increase from one moult to the next in the proportion of $\sqrt[3]{2} = 1{\cdot}26$.

I think it is true to say that neither of these paragraphs possesses any quality that is missing from the other. Both make clear, undecorated statements about the peculiarities of growth in the Arthropoda and introduce a mathematical treatment thereof, and it seems to be immaterial whether the English or the French version is used, because precisely the same impression is in all respects conveyed by both. The contrast between this fact and the failure of any of the translations of the *Aeneid* given above to convey more than a hint of the spirit of Vergil's hexameters is too obvious to need emphasis.

★ ★ ★

In this discussion French has been deliberately chosen as the foreign language concerned, because French is a language that is very different from English in structure, in grammar and in idiom. Indeed it has been said that no one term in French corresponds in all circumstances to one and the same term in English, except of course in scientific, and probably also in other forms of technical writing. This difference, which arises from the fact that English is a Teutonic language, while French belongs to the Romance group, really makes perfect translation of

literary French into literary English an impossibility. However, there are many occasions on which an imperfect translation is preferable to none, so that those concerned with the business of translation make use of a number of agreed rules or precepts which enable a careful writer to produce a version good enough to have a practical value. This makes the act of translation more of a craft than a literary art.

Translation from German into English presents a very different problem. Here both languages belong to the same stock. German sentences have a peculiar rigidity in their structure which makes them easily subject to definite rules, and German words find much more closely approximating equivalents in English. Hence the translation of a German sentence may be compared to the application of a formula, governed by recognised principles. This can scarcely be expected to be true of poetry or other literary work, but it is much more nearly true of ordinary everyday prose and almost perfectly true of scientific writing.

A much shorter example will be sufficient. In this case the original was published in 1937 and the translation in 1952.

> Es gibt Lebenserscheinungen, in denen mehre grosse Probleme gleichsam in einem Punkt zusammendrängt sind. So sehen wir im Spinnennetz und insbesondere in seiner höchstentwickelten Form–das Radnetz – ein Gebilde, das uns unmittelbar an verschiedene Fragen der allgemeinen Biologie heranführt.

> There are vital phenomena in which many great problems are, as it were, concentrated at one point.

Thus in spiders' webs, and especially in their most highly developed form, the orb-web, we see a structure which immediately leads us on to various questions in general biology.

Those who are interested in the art of translation have detected this characteristic feature of scientific prose with some satisfaction: it provides them with the nearest possible approach to perfection in their craft. They must sometimes regret that translations of scientific writings are so rare; for it happens that although a scientist is seldom hailed as a scholar and is often denied a claim even to be considered as educated, he is always supposed to be able to read modern science, and is expected to know the latest work on his own speciality, whether it has been published in French or German, Norwegian or Russian.

Yet he should not complain too loudly about this, for it is, in fact, one of the undoubted stimuli to research. When in the approach to a new scientific problem or in the preparation of a discussion on any scientific topic one tries to follow the steps that have led to the opinion of the day by turning up the many contributions to the journals available in the library of one's choice, the transition from one language to another is a relief and a joy. The unfamiliar tongue may, perhaps, be read more slowly, but when this is the case the return to one's own makes even the peculiarities of scientific prose less conspicuous and less disturbing.

There are plenty of obstacles to scientific research, but the problem of language is not, as a rule, the most formidable.

6

THE VOCABULARIES OF THE SCIENCES

WITHIN the broad confines of science there are many constituent sciences, which, though they freely overlap and contribute to one another's progress, are fundamentally concerned with more or less different objects and different problems. In consequence each has developed its own vocabulary of words more or less peculiar to itself. A biologist never speaks or writes of a parachor, a chemist has no interest in a parasite, a geologist does not worry about a parabola.

The words that are largely peculiar to one science only will of course show, when reviewed and analysed, something of the historical development of the science; they may also reveal a common trend which gives the vocabulary of each science an individual character. To a recognisable extent there is a chemical language, a physical language, a biological language, and others, within the general framework of the language of science; just as there are English, German and Dutch within the group known as the Geomanic languages.

Since all sciences are studies of material things, one of their first tasks is the naming of the substances and objects with which they deal. A name, like sodium or sunflower or sapphire, is no more than a label associated by agreement with some concrete or abstract entity, yet

names are extremely important in science. Until the name of a substance or organism or phenomenon has been chosen, published and accepted, it is impossible either to learn what others have written about it or to tell others what we have thought or what we have discovered ourselves. Essentially the growth of a vocabulary is the same in all the separate sciences, differences arising solely from chance variations.

THE SCIENCES

There are, we said above, several distinguishable 'sciences' which, with the development of knowledge, have established themselves as individuals, marking themselves off as distinctive portions of the old inclusive 'natural philosophy' and claiming the status of sciences in their own right. Many of them have names that end in 'logy', derived from the Greek logos, a discourse, so that collectively they have sometimes been referred to as 'the 'ologies'. 'Maid-servants, I hear people complaining, are getting instructed in the 'ologies,' wrote Carlyle in 1866.

The word anthropology appeared in the English language in 1593. It is most important that the reader should understand that throughout this chapter all historical, dated, references are to words as such and not to the things of which the words are the names. Thus it is not to be supposed that the science of anthropology, as it is recognised and studied to-day, was founded in 1593, but that in that year R. Harvey writing '... the issue they had, arts which they studied, acts which they did. This part of History is named anthropology' used this word for the first time. I do not know when

anthropologists consider their science to have begun, nor is it relevant; the point is that anthropology appears to be the first[1] English word of its kind, and the only one of the sixteenth century.

The seventeenth century added the eleven important words:

chemistry	1606	osteology	1670
archaeology	1607	mineralogy	1690
pathology	1611	pyschology	1693
meteorology	1620	botany	1696
ichthyology	1646	cosmogony	1696
zoology	1669		

Already the tendency towards specialisation is becoming apparent: fish and bones have impressed themselves on the minds of men as objects worthy of study for their own sakes, and the students of these things can say henceforward that they are ichthyologists or osteologists.

The pattern is now set for the next two hundred years. In the eighteenth century one major science acquired a name, geology, 1735, and with it came the birds and trees, the insects and the shells:

ornithology	1706	entomology	1766
dendrology	1708	conchology	1776

The invention of biologie by Lamarck in 1815 has already been mentioned; it is the only name of an important science that belongs to the nineteenth century. The others show the growth of attention to smaller groups, like crabs and mosses:

[1] Astrology was a part of astronomy until the following century when these words acquired their present meanings.

crystallography	1802	palaeontology	1838
stoichiometry	1807	ethnology	1842
petrology	1811	gynaecology	1847
helminthology	1819	histology	1847
herpetology	1824	carcinology	1852
taxonomy	1828	embryology	1859
morphology	1830	bryology	1863
malacology	1836	oecology	1873

The additions of the twentieth century are by comparison an uninspiring lot. Biochemistry appeared in 1902 and protozoology in 1904. The dreadful pestology of 1920 broke away from the parasitology of 1882 with the excuse that many parasites are not pests and many pests, such as locusts, are not parasites. To-day it is possible to find such peculiarities as sexology, musicology and weatherology!

The reader may have noticed that the familiar word physics is not included in the above lists. It is in fact older than anthropology, for it was first used in 1589 in its Aristotelian sense of 'Nature-lore'. The first occurrence in its present sense is found in Gregory's *Astronomy* of 1715.

It will also be noticed that unlike most of the words given above, it does not end in -ology. It seems to be a characteristic of the physical sub-sciences that their names should end in -ics; possibly the tradition was founded by mathematics, 1581. The successors include:

mechanics	1648	dynamics	1788
statics	1656	kinetics	1864
hydrostatics	1660	electrostatics	1867

There are some non-mathematical intruders to this list, which have come from a biological territory:

obstetrics	1829	genetics	1901
bionomics	1888	hydroponics	1938

The origin of the suffix is the Greek -ikos and Latin -icus which carries the connotation of possession or belonging, as in such a word as aquaticus, belonging to the water. The true English form of the suffix is -ic, as in cosmic, hepatic, or tartaric. The final 's' is probably a vestige of the original Greek -ikos which has dropped the 'o': thus hysterikos becomes hysterics; mathematikos, belonging to mathema or learning, becomes mathematics. The latest member of this series is cybernetics, 1946, from kubernao, I govern; it is the study of the governing processes in such complex mechanisms as robot players of noughts and crosses, robot tortoises and other devices which appear to resemble living organisms.

CHEMISTRY

The chemist has had first to name the naturally occurring minerals which provided him with the objects of his earliest experiments, next to name the elements which he has extracted from them and the compounds into which these elements have been made, and lastly to describe and explain any phenomena which have been noticed in their reactions.

The oldest words in the chemical vocabulary betray its Arab origin – alcohol, 1543, from *al kohl*, the powder – and alkali from *al qualiy*, the ashes – are familiar examples. Of the same character are the alchemists' alkahest, 1641, the universal solvent, and alembic, 1374,

the piece of apparatus that is now called a retort. The alchemists had a series of very intriguing names for the various forms of their apparatus: they used not only alembics or limbecks and buyrets (burettes) and crucibles but also cucurbites and matras for their 'digestions and cohabations'.

The word alchemy is itself obviously derived from the Greek *chemia* which meant Egyptian and expressed the belief that the science originated in that country. The Arabs adopted the word and added the definite article al as a prefix. They gave chemistry several other words from their own language as well as some from those of their neighbours. These words include the following:

ARABIC	PERSIAN	SANSKRIT
naphtha	borax	camphor
realgar	cinnabar	indigo
talc	gypsum	sugar
tartar	laudanum	sulphur

The names in the modern list of elements may be seen to fall into five groups.

1. First of all come those which, because they occur naturally or are particularly easily obtained from their ores, have been known for a very long time. Thus the names of gold, silver, lead, iron and tin are found in the Authorised Version, where sulphur appears as brimstone and copper as brass. The names antimony, 1477, mercury, 1563, and arsenic, 1598, were also extant by this date.

2. In the second group are such names as:

zinc	1651	bismuth	1668

manganese	1676	cobalt	1728
phosphorus	1680	nickel	1775

It will be seen that these names were not chosen according to any system, and there is nothing to show whether the substances are metals or not.

3. The matter of nomenclature began to exercise the minds of chemists at about the time of the recognition of the nature of combustion and the composition of water, the end of the eighteenth century. Lavoisier proposed the word carbon in 1789; and, as almost every schoolboy knows, he also suggested oxygen in 1790 and hydrogen in 1791. The name nitrogen was invented, by analogy, by Chaptal in 1794.

4. The great Swedish chemist Berzelius was responsible for the present-day convention whereby the names of metals end in -um. He recognised the value of logical naming and stated his belief that reason and precision in names were a real aid to logical thought, that confusion in names often leads to confusion in ideas. In 1811 he produced a new edition of the *Swedish Pharmacopeia* and included in it a new system of nomenclature. The basis of this was Latin so that he gave metals names like ferrum and zincum. There were several names which already fitted into this scheme:

titanium	1796	potassium	1807
uranium	1797	chromium	1807
tellurium	1800	strontium	1808
palladium	1803	barium	1808
sodium	1807		

All later arrivals or christenings continued it:

platinum	1812	lithium	1818
molybdenum	1816	beryllium	1863

and, of course, all the names of the 'rare earth' elements. Helium, 1878, is the well-known exception; it was discovered by the spectroscope, in the sun's atmosphere, and assumed to be a metal.

5. Non-metals did not seem to fit this system so well. The suffix -gen, noted above, was not used again, and the halogens formed a group by themselves.

Chlorine, 1810, fluorine, 1813, iodine, 1814, bromine, 1826, Boron, 1812, and silicon, 1817, pointed the way to an acceptable alternative, and when Sir William Ramsay discovered in the air a new gas which showed no chemical affinities he called it the lazy one, argon, 1895. Three years later he added neon, krypton and xenon, and the last of the group, niton, was added in 1912.

* * *

From the point of view of chemical progress, it was of greater importance that there should be some system in the naming of compounds. The continued use of such simple names as lime, soda, chalk or hartshorn could only lead to confusion and, foreseeing this, T. O. Bergman (1735–84) suggested that each acid should be given a distinctive name which should be repeated in its salts and thus indicate their origin. This was the germ of the present method, whereby sulphuric acid produces sulphates, and so on.

Five years later, in 1787, four well-known Frenchmen, A. L. Lavoisier, G. de Morveau, C. L. Berthollet and A. F. Fourcroy, submitted to the Académie des Sciences

a new system of nomenclature. This system, essentially the one in use to-day, was intended to show what elements a compound contained and also to make some distinction between different compounds of the same elements. Thus acids were given names which ended in -eux or -ique, corresponding to our -ous and -ic, and their salts bore names ending in -ite and -ate.

This system was more comprehensive than Thomson's, in use in England at the time. It is from Thomson's system that we get the prefixes proto-, deut, tri- and per-, which persist; in fact the modern method is really a combination of Thomson's and de Morveau's ideas.

These regularities were of little value in the naming of organic compounds, but in 1811 not enough organic compounds were known to cause serious difficulties. The following list includes a fair proportion of them:

succinic (acid)	1790	acetic (acid)	1808
tartaric (acid)	1790	oleic (acid)	1819
oxalic (acid)	1791	nicotine	1819
formic (acid)	1791	naphthalene	1821
tannic	1802	butyric (acid)	1826

After the synthesis of urea (1806) by Wöhler in 1828, an achievement which is usually taken to mark the birth of organic chemistry, the number of new names required became very great. The following is no more than a selection of some of the most familiar, from the next fifty years.

alizarin	1835	iodoform	1835
benzene	1835	oxamide	1838
caffeine	1830	paraffin	1835

glycerine	1838	hexane	1877
hippuric	1838	heptane	1877
casein	1841	picric	1838
chloroform	1848	nitraniline	1846
glucose	1840	pepsin	1844
acetone	1858	salicylic	1840
aldehyde	1850	ketone	1851
aniline	1850	phenol	1852
ester	1852	phthalic	1857
glycol	1858	pyridine	1851
acetylene	1864	fructose	1864
anthracene	1863	glycogen	1860
carbamide	1863	methane	1868
carbohydrate	1869	sucrose	1862
cocaine	1874	laevulose	1871
formaldehyde	1873	octane	1872
proteid	1871		

PHYSICS

An unexpectedly large proportion of the vocabulary of physics did not come into being until the eighteenth and nineteenth centuries, and there has been a notable group of additions during the first half of the twentieth. During much of the earlier part of the past two hundred and fifty years physicists of many kinds were engaged in experiments designed to measure, with increasing accuracy, the various quantities that are called 'physical constants'. Work of this kind was inspired and justified by Lord Kelvin's opinion that knowledge cannot be called scientific unless it can be expressed in measurements.

Fundamentally there is undeniably much truth in this; and it is responsible for the general obeisance before the scale and the pointer-reading.

To prosecute these measurements satisfactorily there are two necessities – instruments to respond to the various changes, to carry the scale and to move the pointer across it, and derived units in which to express the results.

The instruments used in the physical laboratories of to-day are numerous. Some of their names end in -scope, because they enable us to see (skopeo, look at) that changes have occurred; the more valuable ones end in -meter, because they enable us to measure (metreo, measure) these changes. But the more interesting things about them are the dates at which their names appeared, illustrating as they do the increasing need for new measurements and the steady development of new devices for making them.

barometer	1665	micrometer	1670
hydrometer	1675	thermometer	1633
hygrometer	1670		
anemometer	1727	manometer	1730
calorimeter	1794	photometer	1760
chronometer	1735	pyrometer	1749
electrometer	1749	vernier	1766
goniometer	1766		
altimeter	1847	planimeter	1858
bolometer	1881	polarimeter	1864
cathetometer	1864	potentiometer	1881
colorimeter	1863	refractometer	1876
dilatometer	1882	sonometer	1808

ergometer	1879	spherometer	1827
hypsometer	1864	voltmeter	1882
magnetometer	1827		

Two of these words invite comment. The hydrometer of 1675 was not an intrument for measuring the specific gravities of liquids, but more literally 'measured water' as a rain-gauge. The vernier immortalises the name of its inventor, Paul Vernier (1580–1637).

The story of the physical units is of course a familiar one, bound up with the invention of the metric system after the French Revolution. The characteristic feature of the derived units is the frequent choice of scientists' names for units often used in the particular field in which they had successfully worked. This habit is rare in chemistry, but is shared with the biologists who frequently adopt the same principle in finding names for animals and plants.

The following is a list of most of the physicists whose surnames have been adapted for this purpose, accompanied by the date at which each physical unit was first taken into use.

A. M. Ampère, 1775–1836	–	the ampère, 1881
C. A. Colomb, 1736–1806	–	the colomb, 1881
M. Faraday, 1791–1867	–	the farad, 1881
K. F. Gauss, 1777–1855	–	the gauss, 1882
J. P. Joule, 1818–89	–	the joule, 1882
G. S. Ohm, 1789–1854	–	the ohm, 1861
A. Volta, 1745–1827	–	the volt, 1873
J. Watt, 1736–1819	–	the watt, 1882
H. C. Oersted, 1777–1851	–	the oersted, 1903
J. Henry, 1799–1878	–	the henry, 1893

Recently the word electron, 1891, has spawned a family of offspring. After the proton came the neutron and the positron, 1934. The bewildered philologist could interpret neutron, but positron was not so simple: it seemed that if the necessity or tradition of an ending in -on were granted, the word should have been positon and that the 'r' had crept in by false analogy with neutron. I myself wrongly assumed this to be the case in my little book on the words of science and believed that cyclotron, 1932, represented another example of the same thing. The existence of magnetron and betatron showed apparently that -tron had established itself as an atomic-physicists' suffix; but all the while the truth was that these words are derived from electron and were intended to imply neutral electron, positive electron and magnetic electron, and so on.

ZOOLOGY

The zoologist has had a much heavier task than the chemist. He has had to name the animals he has found, and in contrast to ninety-five elements he has well over a million different kinds waiting for christening. He has found it necessary to describe their bodies, in ever-increasing refinement of detail, and this has involved the finding of names for all the parts, corners, gaps, projections, 'bits and pieces' of every limb, organ and tissue. This has had to be supplemented by descriptions of the processes of development, growth and functioning of all these limbs and organs as well as the birth and behaviour of the animal as a whole. The result is that the vocabulary of zoology is very large.

As was said in Chapter 3, the zoologists who wished

to describe the bodies of animals found a host of names already awaiting them, names which had been given to the parts of the human body. These they not unnaturally used, so that the thigh bone, for example, of a frog, an ostrich, a lizard or a horse is called the femur. For most vertebrate animals other than fish this custom was acceptable, since the parts that bore the same name were in fact anatomically homologous. It was less satisfactory when the method was extended to the invertebrates, which cannot be compared with man in the same way; and when we speak of the femur or tibia or metatarsus in the leg of a wasp or scorpion we are giving these names to limb-segments which have no relation at all to the vertebrate parts bearing the same names.

This is unfortunate, though it can scarcely be said that it has produced much confusion, for it is equally true that there is no relation between the wing of a bee and the wing of a bird, and yet no confusion follows the use of the same word for both. Moreover the method has obvious limitations, for in many of the small invertebrates the parts and organs are so unlike anything to be found in the human body that the same names cannot possibly be used. For example the orientation of a jellyfish with respect to gravity is the function of eight organs on its circumference called statocysts or tentaculocysts, and no one would think of giving these organs a name that suggested any analogy with the vertebrate ear.

The result is that the types of animals that were among the last to be closely studied have received a long series of names which were composed for the purpose. It is also true that these names have found no

application outside the pages of zoological works and that most of them belong to the nineteenth century. A score are given as examples:

scopula	1802	pleopod	1855
flagellum	1807	telson	1855
palpus	1813	typhlosole	1859
spermatheca	1826	gnathite	1870
cephalothorax	1835	leucocyte	1870
spermatozoon	1836	nephridium	1877
placoid	1842	radula	1877
dolichocephalic	1849	catadromous	1881
pygidium	1849	tornaria	1886
scolex	1853	anopheles	1899
pseudopodium	1854		

BOTANY

The botanist's task differs to a surprising degree from that of his fellow-biologist who studies animals. First, there are fewer kinds of plants than animals, and they are more easily found because they are unable to escape when collectors approach. But there is no plant which is of such universal interest that it was studied by all from the earliest times in the same way as was the body of the animal man; in consequence the botanist did not inherit a set of descriptive terms, more or less applicable to his material, as did the zoologist.

Among the oldest words in the botanical vocabulary are the names of some of the fruits which plants produce in such variety:

pod	1688	siliqua	1704
capsule	1693	follicle	1706

drupe	1753	legume	1785
silicula	1760	achene	1845

but the series of words ending in -carp, from the Greek carpos, a fruit, are generally of later origin:

pericarp	1759	mesocarp	1835
endocarp	1830	epicarp	1835
mericarp	1832	cremocarp	1886

There were no adjectives in existence to describe the many different characteristics of the parts and organs which may vary so widely; hence there rapidly grew up a large number of adjectives which could never be of any use outside the pages of a botanical work, but with which for some years every botanist was expected to become familiar. Examples are:

apetalous	1706	apocarpous	1830
fusiform	1746	baccate	1830
dioecious	1748	epigynous	1830
peltate	1760	napiform	1846
monoecious	1761	piliferous	1846
pisiform	1767	anatropous	1847
perigynous	1807	extrorse	1858
hypogynous	1821		

As botany outgrew this emphasis on the description of the flowering plant and botanists began more and more to remember that a plant is a living organism, these terms to some extent lost their popularity, but have been displaced in the student's vocabulary by the words of the ecologist and plant physiologist. Examples are:

photosynthesis	1804	phylloclade	1858
chlorophyll	1810	saprophyte	1875
phyllode	1848	plastid	1876
antherozoid	1854	symbiosis	1877
spermatozoid	1857	plasmolysis	1855

Just as the vocabulary of invertebrate zoology tended to follow that which referred to man and the other vertebrates, so the vocabulary of the flowering plants (phanerogams, 1821) was followed by much of the vocabulary of the non-flowering ferns, mosses and fungi. Among many examples, all belonging to the nineteenth century, are the following:

indusium	1804	lodicule	1864
mycelium	1836	coleorhiza	1866
sporangium	1836	conidium	1870
androecium	1839	pyrenoid	1883
bacterium	1847	haustorium	1875
diatom	1854		

I have said in an earlier chapter that the terms of science do not fit easily into the language of verse, but, in at least one instance, Mr John Betjeman thinks otherwise, for he has lately written:

A grassy kingdom sweet to view
With tiger lilies still in flower
And beds of umbelliferae
Ranged in Linnaean symmetry
All in the sound of Magdalen tower

BIOLOGY

It is illogical to treat biology separately from zoology and botany, but it is convenient to do so. The criteria

which distinguish living from lifeless objects are common to animals and plants, so that there is a vocabulary of a common value, especially that part of it concerned with nomenclature.

One of the most interesting features about the language of biology is the fact that in naming plants and animals the biologists have taken the Latin language into their science and made it an indispensable part of their mode of expression. The system of binomial nomenclature established by Carl Linnaeus, though not invented by him, gives every organism a name consisting of two or three Latin words. Of these the first is the generic name and the second is the trivial name, and the two together constitute the specific name. The third when present is the name of the sub-species. Probably the most familiar is Homo sapiens. In this example it is clear that Homo, man, the generic name, is a noun and sapiens, wise, is an adjective agreeing with it. This is the most usual kind of name, but sometimes the trivial name is a second noun in apposition with the first, as in Felis leo, the lion, and Daphne laureola, the laurel: sometimes it is a noun in the genitive singular or plural as in Pieris brassicae (of the cabbage) or Helix desertorum (of the deserts) and sometimes it preserves the name of a biologist as in the name of the bat Myotis daubentoni.

The point to be emphasised in connection with these names is that they are an integral part of biological phraseology in the sense that they are universally used in their Latin form and never in a translated form. It is possible to 'explain' them and to help others to understand and remember them by saying that Lepus cuniculus means the burrowing hare, but biologists

themselves never do this.[1] The animal that had made perhaps as large a contribution to biological theory as any other is the little fruit fly, Drosophila melanogaster, and no one dreams of referring to it as the black-bellied dew-lover.

Biological nomenclature also makes use of certain characteristic suffixes such as -oidea, -idae, and -inae. The most important of these is -idae, which is the correct termination for all names of families. Thus a family of amphibians of which the typical genus is Rana must be given the name Ranidae. The termination is derived from the Greek eidos, resemblance, so that the family name means resembling Rana.

Sometimes a family is divided into sub-families, the names of which then all end in -inae. This is a modern invention, belonging to the 'New Latin' which biologists have had to adopt or invent. Similarly, families are sometimes grouped together in categories or cohorts between the family and the order, and these groupings are often given the termination -oidea, as in Sipunculoidea.

A practical difficulty is the large number of names that must be found or invented – the zoologist has to deal with well over a million species while the botanist is relatively fortunate with about three hundred thousand only. Hence it is most probable that a biological reader coming by chance on a name such as Symphoricarpus or Anelasmocephalus will not know the kind of organism

[1] And with some reason, for translation sometimes gives curious results. Thus Tortrix viridiana means The twisted woman living among the green and Mitopus morio means the Thread-foot fool. These are not really apt names for the moth and the harvest spider that bear them.

to which it belongs, unless it has come from within his own speciality.

Some authors are practically helpful in this matter when they have to name a series of genera. The best example is perhaps to be found in the names of the genera of fleas:

Ceratopsylla	=	horn-flea
Ischnopsylla	=	thin flea
Leptopsylla	=	slim flea
Ornithopsylla	=	bird flea
Spilopsylla	=	spotted flea
Xenopsylla	=	strange flea

all of which announce their own nature as clearly as is possible. It may not be possible to follow this example in very many groups, but when it is done it shows us a taxonomist who is aware of the fact that the names of organisms are a part of the language of science and as such are the better when they have a real meaning.

★ ★ ★

Another branch of biology which is common to both zoology and botany is the science of genetics. Almost the whole genetic vocabulary has been created in the last fifty years, for although it was possible to give new usages to such words as dominant, recessive, and even meiosis, it has been necessary to invent a number of others. Some of the latest words in the geneticists' vocabulary are among the most horrific collections of syllables that scientists have ever put together; among the older words are:

nucleolus	1845	allelomorph	1902
mitosis	1882	gene	1909
chromosome	1890	meiotic	1915

The geneticists now measure the distance between two genes on a chromosome in a unit of their own, the centimorgan. In thus adapting the name of Prof. T. H. Morgan, the great American geneticist, they have followed the custom of the physicists, mentioned earlier in this chapter.

GEOLOGY

The geological vocabulary admits a less satisfactory treatment than does that of some of the other sciences. Partly this is due to the fact that in speaking or writing of land-forms the geologist can often use the words familiar to the admirer of scenery – words such as flood, plain, fault and others which scarcely rank as words of science – and partly to the fact that in describing the nature of rocks and minerals he can use terms and names which one tends to think of as primarily chemical.

Moreover, it is a fact that the nomenclature of minerals has never been brought into any system of rules, as has the naming of plants and animals. They have always been named according to the whim of their discoverer or describer, and they still are: and the name may be derived from some peculiarity in the mineral itself, as graphite refers to the fact that the substance can be used for writing, or from the locality where it was first found, like greenockite, or from the name of the discoverer or anyone else, like glauberite.

Apparently it does not matter to a mineralogist if the

same mineral has been differently christened by different workers, so that the names of minerals are never followed by the names of their authors, as are the names of animals and plants. This is probably because the identity of a mineral is easier to determine than that of an animal, since the results of chemical analysis are less open to doubt than is the process of comparing a specimen with a written description.

Occasionally the name of a mineral calls to mind an ancient superstition, as the name amethyst, from *a*, not, and *methyo*, to intoxicate, recalls the ancient belief that wine drunk from an amethyst wine-glass was deprived of its power of intoxication. Sometimes the name of a mineral gives a hint of its chemical composition, for example, argentite and cuprite obviously contain silver and copper respectively; but sometimes the reverse is the case and the element's name has been given to it after its extraction from the ore. This has happened to zirconium, for instance, the metal contained in the mineral zircon. Sir Humphrey Davy failed to isolate metals from several of the minerals in which he sought them, and in 1808 he wrote: 'Had I been so fortunate as to have procured the metallic substances I was in search of, I should have proposed for them the names of silicium, alumium, zirconium and glucium.' Zirconium was in fact isolated by Berzelius in 1824. The others received different names from their investigators, for silicium proved to be a non-metal so that Berzelius called it silicon in 1817; and Wöhler, who isolated the others, called them aluminium and beryllium in 1827 and 1828 respectively.

These facts are established by a glance at the names

of a few representative minerals, here arranged according to the century in which each name arose:

SIXTEENTH		SEVENTEENTH	
agate	1570	cadmia	1657
haematite	1543	calamine	1601
malachite	1567	galena	1671
opal	1591	gypsum	1646
pyrites	1567	mica	1684
selenite	1567	molybdena	1693
silex	1592	obsidian	1656

EIGHTEENTH		NINETEENTH	
barytes	1789	apatite	1803
felspar	1757	aragonite	1803
fluorspar	1794	atacamite	1837
graphite	1796	bauxite	1868
olivine	1794	cassiterite	1858
quartz	1756	cryolite	1801
zeolite	1777	kainite	1883

Crystalline ores and minerals are generally found in the metamorphic rocks: the stratified rocks, which are of greater interest to the palaeontologist and biologist, are more closely associated with the three epochs, palaeozoic, mesozoic and cainozoic, and their included eras, into which the past history of the world has been divided. There are three eras, the names of which were in use long before geologists borrowed them; they are Devonian, dating from 1612, Cambrian, 1656, and cretaceous, 1675. The rest, with but one exception, are all nineteenth century inventions. These words are given here in two columns; the first puts them in the

customary order of geological succession, the second arranges them in philological historic order:

Cainozoic epoch	1854	carboniferous	1799
pleistocene era	1839	cretaecous	1832
pleiocene	1833	pleiocene	1833
miocene	1833	miocene	1833
oligocene	1859	eocene	1833
eocene	1833	Jurassic	1833
Mesozoic	1840	Cambrian	1836
cretaceous	1832	Devonian	1837
Jurassic	1833	palaeozoic	1838
triassic	1841	pleistocene	1839
Palaeozoic	1838	mesozoic	1840
permian	1841	triassic	1841
carboniferous	1799	Permian	1841
Devonian	1837	Silurian	1842
Silurian	1842	cainozoic	1854
ordovician	1887	oligocene	1859
Cambrian	1836	ordovician	1887

The group of 1833 are derived from Sir Charles Lyell's famous book, *The Principles of Geology*.

Some of these names have found their way with advantage into the biological province of nomenclature mentioned above.

The series Eohippus, Miohippus and Pliohippus gives the reader a chance to recognise the fact that these names are those of a group of fossil horses (hippos, a horse) found in the different strata the names of which are suggested.

7

THE SCIENTISTS AND THEIR LANGUAGES

THERE would be no language of science at all if there were no scientists to write and read it. If therefore we are to complete a study of this language it seems to be desirable that something at least, should be said about the minds that use this language, the minds which, with the powers and limitations common to all men, have brought it into existence.

Scientists differ from other men only in the type of education to which they have been subjected, and the point of view which, because of that education, they adopt. It is, therefore, a difference which begins to appear early in the scientist's life and which lasts until its close.

In the beginning the path of the young scientist is no rougher than those of his companions; indeed on occasions it runs smoothly and pleasantly downhill, so that he travels cheerfully while his comrades are toiling, struggling, sweating up the foothills of Parnassus or Olympus. But his path goes far; it passes the horizon and stretches onwards to infinity, an unending journey which he can never hope to finish. Never to finish, but he must travel a very long way; and so, because his day contains no more than twenty-four hours and his week no more than seven days, he must keep his eyes fixed

on his unattainable goal, spare no glance for the beauties of the surrounding country, hold no converse with his less harassed fellow-travellers.

Let us translate this allegory into the common prose of the student's life. Come with me, for example, into the advanced chemical or physical laboratory, the gift or legacy of some industrial benefactor, in Redbrick University; come, if it please you, after tea on a bright afternoon in summer, and we shall find it full of serious undergraduates occupied in earnest experiment. Let us engage one of them in conversation, learn the nature of his task, and ask him how many hours a week he spends in laboratory, in lecture room, in private study. His answer, I am confident, will be a revelation to any linguist, classic or historian. And if, impressed by such devotion and surprised by such single-mindedness, we ask: 'But how much time do you find for exercise, for your cricket or tennis, how much for relaxation, for the theatre, or the concert hall, how much for social life, for the union, the common room?' he is likely, with a smile at our innocence, to answer us in a word, 'None'.

This is hardly an exaggeration; it is happening all over England to-day. Science demands of its devotees so absolute an allegiance that the enthusiast has no time for culture; 'no time to stand and stare', (no time but to confess in the words of Horace, '*Parcus deorum cultor et infrequens*') Of course, it is not his fault. Very probably he has few regrets, and would not cross to another path of learning should he come upon a track that would lead him aside. We admire his enthusiasm; but we must ask to be excused if we believe that travellers on the other roads have experiences that he

cannot share. He is no prisoner, but he is blinded by the brilliance of a light known as 'science'.

★ ★ ★

We have already discussed science from the outside; but this outward appearance is only a half of the matter. There is a subjective implication in the word science, which can be fully appreciated only by the scientist himself, just as in the word art there is an implication which can be understood only by the artist. This aspect of science includes the peculiar or characteristic mode of thought of the scientist, the ambitions which he sets before himself in his passionate endeavour to reveal the unknown, and the satisfaction, rising at times to ecstasy, which envelops him whenever a success has brought him a step nearer his goal. This intimate faith of the scientist is intangible, and difficult to put upon paper: its clearest expression is to be found in the writings[1] of Dr J. R. Baker, who, more than any other living author, is the eloquent apostle of this influence of science on the individual who follows it.

A parallel can be found in the art of music, where a similar relationship exists between performance on an instrument and the state of mind of the performer, and where there is also the same difference between the mediocre player and the true musician. A machine can be made to play a piano and, as at least one scientist finds, to produce sounds which are no more repellent than those of a human pianist; but in the mind of the latter and the more gifted members of his audience, there is a hint of something else,

[1] *The Scientific Life* (1942) and *Science and the Planned State* (1945).

of magic casements, opening on the foam
Of perilous seas, in faery lands forlorn;

something of which Browning wrote: '*The rest may reason, and welcome; 'tis we musicians know.*'

The mind of the scientist does not easily find expression for its sentiments in words of such quality, but undeniably the faith is there.

This faith supports many of the actions of the scientist, and it may, perhaps, be possible to paint a picture of its inspiring force, to suggest something of its capacity and to display its many-sided operation by recounting a few instances of its power, as shown in the deeds or words of scientists themselves.

When in 1919 Sir Ernest Shackleton was lecturing in the Philharmonic Hall on his experiences during the *Endurance* Expedition, he showed his audiences a lantern slide of trawling apparatus and, 'There,' he said, pointing to a human figure, 'is that incurable optimist, the biologist. Give him,' he added, 'a worm half an inch long and he is happy for a month.'

It would not be difficult to argue that optimism, a desirable facet of character in all walks of life, is one of the most important assets of a scientist. It must lie at the base of all those impulses which drive a scientist to carry on researches of which the immediate practical application or monetary advantage is obscure. Yet it is too well known to need emphasis that all the best scientific work is of this character. The scientist must be left free to follow his self-chosen course: planned research, if that is not a contradiction in terms, is an almost fatal obstacle to success; while the whole of the

history of applied science is a story of the finding of solutions to practical problems in the results of pure research carried on without any thought of its usefulness, or indeed without any definite wish that such usefulness should be found.

Dr Baker has dealt with this feature of research so adequately and has given such cogent proof of its truth that it would be an impertinence to attempt to cover the same ground here. It is, however, a part of the character of the scientist which could not be omitted altogether; and it will therefore be sufficient to quote the words of Prof. T. D. A. Cockerell who, many years ago, wrote thus: 'The work which seems to an outsider hopelessly petty and trivial may reveal the hidden forces of the universe, or may afford means of dealing with the most pressing problems of mankind. The individual naturalist does not usually expect to attain any far-reaching results, but he knows that he is contributing to a structure of knowledge which, when reasonably complete, will begin to yield fruits of a kind that he may only dimly foresee. His faith is that the building will be serviceable, and all human experience goes to justify it.'

This faith manifests itself in the work of many scientists. They often surprise the ordinary man by an enthusiasm which seems to take no heed of circumstances which would deter a worker in many other branches of human endeavour. Dr Chalmers Mitchell has given us a glimpse of one instance of this enthusiasm in a passage in his autobiography, *My Fill of Days*, where he describes some of his work at the Zoological Gardens. 'In a piece of research which occupied my leisure for years, my material was the intestinal tracts of creatures which had

died at the Zoo, and offered every kind of loathsome odour. I have gone out of the laboratory to vomit, and come back cheerfully to my job.'

At the beginning of this chapter we drew a parallel between the scientist and the traveller; we may now continue it with a parallel between the scientist and the explorer. The comparison is so obvious that it needs no elaboration; but it is doubly interesting, because both words have insensibly changed their associations in the course of a generation. It used to be said in the early years of this century that the word 'explorer' conjured up in the mind a picture of a man in bulging windproof clothing, hauling a sledge across the snows of Antarctica; to-day the same word suggests a man sitting at ease in an aeroplane, watching the dials of his instrument panel while an automatic camera takes ten pictures a minute of the ground below him.

In the same way the word scientist used to evoke a picture of a man at work in a laboratory, surrounded by complicated apparatus and an atmosphere of mystery; to-day it is quite as likely to suggest a picture of a young woman in a white overall, intent on the adjustment of a screw and radiating an aura of sex-appeal.

The truer meanings of both words are seen when the occupations are united in the labour of the same man. Most of the explorers of to-day are scientifically-minded and the two enthusiasms blend to form a devotion that is a refreshing corrective to the cynical atmosphere of a disillusioned age. I do not know many paragraphs which give a more convincing picture of this union than that written by my old pupil, Dr F. D. Ommanney.

Let me leave in your minds a picture of the occasion when we dredged in shallow water in the Ross Sea in seventy-eight degrees south. It was blowing a wind off the Antarctic Continent that seemed to cut the skin like a razor. The dredge, a conical canvas bag attached to a stout iron frame which was dragged along the sea floor, came up full of yellowish mud. This was emptied out in a heap on the poop deck. We had to look through it in search of rock specimens, preserve samples of it in jars of alcohol, and wash some of it in sieves. The yellow heap of sticky clay was so cold that one immersion of the hands in it paralysed them completely up to the wrists. We went over every inch of this freezing pile of slime, plunging our hands in it over and over again up to the wrists, squeezing the oozey clay between our fingers. We did it with tears. Fire-walking could scarcely be a more painful ordeal.

* * *

The popular conception of the scientist has for a long time been one of a coldly unsentimental person, either lacking experience of ordinary human emotions or at all events unable to give them expression. Conan Doyle, for example, wrote a short story of a scientist who fell unluckily in love and died of a broken heart. His colleagues, discussing his death and unable to accept its true cause, concluded with the dictum: 'Let us call it cardiac.' One might further quote a scientist's comment on the Derby: 'That one horse can gallop faster than another has long been known; why go to Epsom to see it?'

The origin of all this lies in the fact that the scientist, as such, studies only matter, material events and material changes, and for preference studies only those events or changes which can be measured. Indeed, much of the practical ingenuity of the scientist is directed to causing events, which normally appear to the mind as sensations, to appear as pointer-readings on a scale.

Much exists, however, which has so far defeated this ingenuity, and therefore remains purely qualitative or descriptive. A man is unable for example to express his love for his mother, his wife, his sister and his daughter in four numbers, and so to compare them; nor can numbers be used to express or compare the beauty of a silver birch, a spider's web and the Vale of Evesham. In consequence there is no scientific contribution to the study of love and beauty; or, as one recent scientist has complained:

How much I love you cannot be assessed,
There is no calorie, no volt, no dyne
By which to plumb a passion such as mine,
And Science fails to help me, so obsessed.

It follows that all scientific knowledge and all scientific opinion are knowledge and opinion about matter and material events. This fact has led to a rather widely spread idea, of which the remarks above are examples, that science must support a materialistic philosophy or, going even further, that science can justify such a philosophy, and that scientists must hold it.

It should be clear that such a belief could only be held by anyone who limits his thoughts, words and deeds exclusively to science, or at least so largely to science

that the other aspects of life are making no significant contribution to his character. Perhaps there are people like this, for one of them described science as 'something which fills the mind, directs the thoughts, determines the arguments, selects the method and destroys the mystery'.

It must also be clear that if a man chooses thus to limit his thoughts, he alone must be responsible for any consequences that follow. The terrible dullness of his outlook and the sterility of his life will be his own fault: they cannot be the fault of science. ✓

* * *

The bulk of this book has been concerned with English words and phrases of English literature; little attention has been paid to the fact that science is often written in other languages, and at this point it is instructive to recall the advice that at one time was commonly given to young scientists, given with every desire to be helpful. It was that they should learn to read German. Indeed at one time it was almost true to say that the language of science was the language of Heidelberg and Göttingen.

The advice was undoubtedly justified. Twenty-five years ago I compiled for my book, *The Biology of Spiders*, a bibliography of three hundred and nineteen fundamental papers and books and almost exactly one-third of these were German. Many scientists will agree that in the first forty years of the present century it was if not impossible at least exceedingly difficult to keep abreast of any branch of biology or medical science if one did not read German. I suspect that probably the same

was true of other branches of science with which I cannot claim the same acquaintance. Yet, as we daily realise, times change; the results of biological and medical research in Germany have been very meagre during the period since 1939, and there does not seem to be much evidence that they will become appreciably greater for some time.

Moreover a curious change has begun to spread over the world of science. Workers in the Far East, in Denmark and the Scandinavian countries used at one time to publish the results of their work in German. They knew that the Japanese and Norwegian languages were not widely read outside their own countries, and they sought greater appreciation of their efforts by having their work translated into a language more widely understood. To-day the work in these countries, and others, is very largely published in English: and with the ever-expanding and very practical interest in science, both in America and in many parts of the British Empire, English shows signs of becoming the language of science.

The implication of this is that the desirability of learning foreign languages may tend to decrease, and there have been writers who would not have regretted this. Herbert Spencer, for example, believed that the study of languages promoted an undue respect for authority, and that by so doing it delayed the growth of the power of independent judgment. Prof. William Ostwald, a great German chemist and also a great teacher of chemistry, went further than this. He thought that there was reason to suppose that the customary and somewhat stereotyped methods of teaching Latin tended

to stifle the spirit of scientific enquiry, and that in consequence a scientist, particularly one engaged on research, should even avoid the study of languages and make no attempt to learn them.

There are many to whom these opinions are unacceptable, and indeed they can scarcely expect to be received with very general agreement. Certainly there must be a difference between the discoverers who make science, and the students who learn it. Those who find no intellectual pleasure in reading foreign languages, or perhaps even in trying to read them, must admit that some ability to do so is of practical value. I am not sure that the increased effort that is necessary to master a scientific paper in another tongue does not result in a more thorough understanding of its contents and a more secure place for them in one's over-crowded and always imperfect memory. Very possibly it is true that during the three hectic years of intensive study that culminate in the Tripos, or its equivalent, the student is wise to devote a large, a very large, proportion of his time to science. But the day comes – and its arrival is indeed one of the supreme moments in experience – when the Tripos is a thing of the past.

Until this moment the student is apt to estimate his scientific ability by the number of facts he can remember, and reproduce if necessary in examination. But when, after his Tripos, he forgets most of the facts, as all of us do, he does not cease to be a scientist. And he realises that he must continue to learn, and that the time spent on languages is time lost to science. His problem therefore is that which faces, more or less urgently, every actively-minded scholar, the problem of competing interests. He

has to decide what he can neglect: but how, in the absence of a recognised relative value of knowledges (to use Bacon's phrase) can he, or anyone else, supply the best answer to his question?

Prof. W. I. B. Beveridge, who has discussed this problem in *The Art of Scientific Investigation*, points out the advantages of a study of the principles of statistics. No doubt statistical methods are coming to play a more and more decisive part in research, yet Prof. Beveridge also regrets that scientists can find so little leisure for general literature. The question is one that every scientist must answer for himself, and the wisest advice can only be a clear statement of the alternatives. And if a scientist's surplus of intellectual curiosity does not turn towards statistics, it might be allowed to satisfy itself in a study of English – or Greek. *Chacun à son goût:* the most important thing is that the scientist should cultivate some other interest outside his science, and in so doing should recognise that there are some outside interests which will enrich his science more than others.

* * *

Yet, among all these opinions and suggestions, it must not be forgotten that other languages than English are in fact also used by many scientists. Dr R. F. Lawrence of Pietmaritzburg has lately made a most interesting analysis of the languages in which original zoological research has been written during the past ninety years. His data have been provided by the *Zoological Record*, which began annual publication in 1865. There is no reason to suppose that in this matter the other sciences are significally different from zoology, but there appears

to be available no comparable source from which the facts may be obtained.

Dr Lawrence's investigations show that five major languages, English, German, French, Spanish with Portuguese, and Russian, have been used for about 90% of the world's zoological publications. Of these English has contributed a fraction which has never fallen below 40%, and which in recent years has shown a tendency to rise. This quantity, it is pointed out, is disproportionate to the actual number who look upon English as their natural tongue, and Dr Lawrence ascribes the preponderance in part 'to the immense economic prestige and industrial power of the United States', and in part to the much higher general level of education among the British and American people. If this is so there seems to be every reason to suppose that the dominance of English, at present obvious enough, will continue to become more and more marked until it will be universally recognised that the language of science is English.

The German percentage has shown an almost continuous drop from 31% in 1880 to 9·1% in 1948, but with a sharp temporary rise to 33% between 1905 and 1910. French has been steadier than German; French science made a slower recovery than German science after the first world war, but a more rapid one after the second war. Russian which has never been used for even 5% of the world's zoological literature shows no more sign than French or German of expanding its influence.

The one European language which has steadily increased its usefulness during the past twenty-five years is Spanish, and the day may come, perhaps, when

it will take second place to English. Whether this occurs or not, there is at present no evidence to suggest that the general use of English will be seriously challenged.

Other languages need not detain us long. One of the most interesting points which Dr Lawrence has made is that since the first world war national pride has been responsible for the appearance of scientific papers in languages which had not been seen before. The newcomers, which include Afrikaans, Chinese, Hebrew, Latvian and Ukrainian, bring the total number of all languages used in science to twenty-nine.

It is worthy of mention that nearly all the contributions to science which have been written in the less widely used languages have been followed by a summary in English, French or German. Such summaries may not be quite as useful to the working zoologist as the whole paper, but they are a great deal better than nothing, and readers should recognise their gratitude to the fellow-scientists who provide them.

In particular the Dutch, Norwegians and Danes have gone further, for they have frequently published their whole papers in one of the three languages just mentioned in preference to their own. They have sunk national pride in the choice of a language which, because it is more widely read, must work for the greatest good of the greatest number. Manifestly, there must be many thousands of scientists in England and France who will emphatically prefer to read their science in German rather than in Norwegian or Dutch; and all these will gratefully admit their indebtedness to a national convention which cannot be overpraised.

We who wrote our scientific papers in English are

not expected to add a précis in, say, Bulgarian or Japanese; we might well be surprised if we were asked by our editors to do so; but if we had to do such a thing, we should also realise that the additional trouble involved has for a long time been taken, as a matter of course, by many scientists in east Europe and Asia. The writers of English have long been favoured, while the writers in other tongues have been making a practical contribution towards the internationalism of science and the understanding of the nations one with another.

It follows, perhaps, that the impression produced by this chapter is that many obstacles lie in the path of the student of science. Some of these can be traced to the nature of all scientific or other learning, others originate in the nature of the scientist himself. There can surely be nothing as effective as a study of science in making man aware of his limitations and in forcing upon him a modest estimate of what he is likely to achieve. The pursuit of scientific truth is often its own reward, and as a rule it is not rewarded in any other way. A real scientist would not have it otherwise; his point of view was finely expressed a generation ago in the closing sentence of Cherry-Garrard's *Worst Journey in the World:* 'If you march your Winter Journeys you will have your reward, so long as all you want is a penguin's egg.'

* * *

I conclude this chapter with a very small sample of comparative scientific nomenclature. Those who take no interest in other languages can pass it by, while for those who respond to the fascination of foreign speech it will need little commendation. To them it will

suggest the compilation of a private notebook on similar lines, but with the number of categories, of items in each category and of languages included all much increased. Such a book supplies an occupation for leisure that compares very favourably with many other forms of self-entertainment.

To the reader of science there is one point which these short lists[1] bring out very clearly. It is that in reading science in a foreign language it is not the scientific words that produce the difficulties; they are often so similar in all languages as to be easily recognised. It is the words that carry such meanings as although or underneath or probably that make a sentence strange or obscure, and so help to emphasise what is certainly a definite though an obvious characteristic of the language of science.

[1] Vide pages 160–3.

ENGLISH	GERMAN	SWEDISH	FRENCH	SPANISH	ITALIAN
			ELEMENTS		
Copper	Kupfer	koppar	cuivre	cobre	rame
Gold	Gold	guld	or	oro	oro
Iron	Eisen	järn	fer	hierro	ferro
Lead	Blei	bly	plomb	plomo	piombo
Mercury	Quecksilber	kvicksilver	mercure	mercurio	mercurio
Silver	Silber	silver	argent	plata	argento
			COMPOUNDS		
Chalk	Kreide	krita	craie	greda	creta
Clay	Lehm	lera	argile	arcilla	argilla
Glass	Glas	glas	verre	vidrio	vetro
Marble	Marmor	marmor	marbre	marmol	marmo
Salt	Salz	salt	sel	sal	sale
Vinegar	Essig	ättika	vinaigre	vinaigre	aceto
			MINERALS		
Asbestos	Asbest	asbest	asbeste	asbesto	asbesto
Cinnabar	Zinnabar	cinnober	cinabre	cinabrio	cinabro
Galena	Bleiglanz	galena	galene	galena	galena
Granite	Granit	granit	granit	granito	granito
Gypsum	Gips	gips	gypse	yeso	scagliola
Malachite	Mal	malakit	malachite	malaquita	malachite
			GEMS		
Diamond	Diamant	diamant	diamant	diamantado	diamante
Emerald	Smaragd	smaragd	émeraude	esmeralda	smeraldo
Opal	Opal	opal	opale	opalo	opale
Ruby	Rubin	rubin	rubis	rubi	rubinoso
Sapphire	Saphir	safir	saphir	zafiro	zaffiro
Topaz	Topas	topas	topaze	topacio	topazio
			VERTEBRATES		
Cat	Katze	katt	chat	gato	gatto
Dog	Hund	hund	chien	perro	cane
Frog	Frosch	groda	grenouille	rana	ranocchio
Horse	Pferd	häst	cheval	caballo	cavallo
Rabbit	Kaninchen	kanin	lapin	conejo	coniglio
Sheep	Schaf	far	mouton	oveja	pecora

ENGLISH	GERMAN	SWEDISH	FRENCH	SPANISH	ITALIAN
			BIRDS		
Blackbird	Amsel	koltrast	merle	mirlo	merlo
Eagle	Adler	örn	aigle	aguila	aquila
Heron	Reiher	häger	héron	garza	airone
Owl	Eule	uggla	hibou	buho	gufo
Seagull	Möwe	mas	mouette	gaviota	gabbiano
Sparrow	Sperling	sparv	moineau	gorrion	passero
			INVERTEBRATES		
Ant	Ameise	myra	fourmi	hormiga	formica
Bee	Biene	bi	abeille	abeja	ape
Fly	Fliege	fluga	mouche	mosca	mosca
Snail	Schnecke	snigel	colimaçon	caracol	chiocciola
Spider	Spinne	spindel	araignée	arana	ragno
Wasp	Wespe	geting	guêpe	avispa	vespa
			TREES		
Ash	Esche	ask	frêne	fresno	frassino
Beech	Buche	bok	hêtre	haya	faggio
Elm	Ulme	alm	orme	olmo	olmo
Oak	Eiche	ek	chêne	roble	quercia
Pine	Kiefer	tall	pin	pino	pino
Willow	Weide	pil	saule	sauce	salcio
			FRUIT		
Apple	Apfel	apple	pomme	manzana	mela
Grape	Traube	vindruva	raisin	uva	uva
Lemon	Zitrone	citron	citron	limon	limone
Orange	Apfelsine	apelsin	orange	naranja	arancia
Pear	Birne	päron	poire	pera	pera
Plum	Pflaume	plommon	prune	ciruela	susina
			CROPS		
Barley	Gerste	korn	orge	cebada	orzo
Cabbage	Kohl	kal	chou	col	cavalo
Carrot	Karotte	morot	carotte	zanahoria	carota
Potato	Kartoffel	potatio	pomme de terre	patata	patata
Rice	Reis	ris	riz	arroz	riso
Wheat	Weizen	hvete	froment	trigo	frumento

ENGLISH	GERMAN	SWEDISH	FRENCH	SPANISH	ITALIAN
			NUMERALS		
One	ein, eine	en, ett	un, une	uno, un, una	uno, un, una
Two	zwei	twa	deux	dos	due
Three	drei	tre	trois	tres	tre
Four	vier	fyra	quatre	cuatro	quattro
Five	fünf	fem	cinq	cinco	cinque
Six	sechs	sex	six	seis	sei
Seven	sieben	sjn	sept	siete	sette
Eight	acht	atta	huit	ocho	otto
Nine	neun	nio	neuf	nueve	nove
Ten	zehn	tio	dix	diez	dieci
Eleven	elf	elva	onze	once	undici
Twelve	zwölf	tolv	douze	doce	dodici
Twenty	zwanzig	tjugo	vingt	veinte	vente
Hundred	hundert	hundra	cent	ciento	cento
Thousand	tausend	tusen	mille	mil	mille

8

THE LITERATURE OF SCIENCE

THE STUDENTS of a language cannot limit themselves to a knowledge of its words and its grammar; they are expected to acquire some familiarity with its literature. Hence a study of the language of science cannot be said to be complete without an examination of the literature which that language has produced.

The literature of a nation includes works of widely different kinds. A lover of English literature will read much more than the plays of Shakespeare and the epic poems of Milton: he must gain acquaintance with narrative, with allegory and satire, with fiction and so on. Moreover, the reader of Chaucer, of Dryden, of Dickens is usually reading for personal pleasure or entertainment; he is seldom reading for information. Reading, mankind has long since discovered, is one of the most delightful occupations, acting as a mental restorative or recreation because it provides the mind with relief from the problems of normal living.

The literature of science stands in sharp contrast to this. It is nearly always informative; either it presents the reader with important facts or it compels him to think about these facts and their significance, and so cannot be described as restful. The proportion of scientific literature which is recreational is small, but, as will be seen, it is not negligible.

Another point is of fundamental importance. The literature of a country or of a race is contained in its printed books. And where else, asks the surprised reader, is it to be expected? Any scientist who has carried out a piece of research will answer that at the beginning of an attack on any problem his first task is to look up the existing 'literature'. To do this he turns first to the recent issues of the relevant scientific periodicals. In science knowledge advances and opinions change very rapidly; all original work to-day is first given to the world in the pages of journals, and indeed if it ever finds its way into a printed book it is likely by then to have been superseded by even more recent progress. To the actively working scientist, therefore, the journals are of first importance, not the books.

Yet the papers published in scientific periodicals are very seldom 'literary',[1] and cannot in any way be said to constitute the literature of science in the sense normally implied by that word. They are related to it as is the daily newspaper to the history book, and in the long-time view it is the book that exerts the permanent influence; it is the book that contains the real literature and only books can so be considered.

This gives the books of the scientists a special nature, almost peculiar to themselves. To the ordinary man the chief characteristic of scientific books might well seem to be their small circulation and their high price. A much more important characteristic is their impermanence which they derive from the facts mentioned above. A

[1] Proof of this – in 1950 a well-known scientist occupied a full column in a scientific weekly with an effort to explain how two mutually contradicting statements which he had made were supposed to be in harmony and, more surprisingly, that both were correct.

Goldsmith's *Deserted Village* may retain its interest for generations, for centuries; a Lavoisier's *Traité de Chimie* does not, save as a curiosity, or to those rare scientists who are concerned with the history of their subject. Collectors of old scientific books are few; indeed the price at which copies of once-famous books can now be obtained suggests that, in view of the growing interest in the history of science, these books offer a most attractive proposition to the speculative bibliophile. The whole position is summarised in the statement that whereas an ordinary book-lover prizes the first edition, the scientist seeks the last.

* * *

If an Englishman, well-read in the history and literature of science, were asked to name the books that may be called the classics of science he would be likely without much hesitation to suggest Newton's *Principia*, Boyle's *Skeptical Chymist*, Faraday's *Chemical History of a Candle* and Darwin's *Origin of Species*. The first of these would have to be omitted since it was not written in English, and probably it is unlikely that we shall arrive at a list of the classics of science by asking questions that are to be answered 'without hesitation'.

If it be true that the 'classics' are the works which the reading public continues to demand, a possible way to discover what these books include will be to consult those, the publishers, whose work it is to satisfy this demand. A promising line of enquiry is to turn to the list of titles given under the heading of Science in the catalogue of the famous *Everyman's Library*.

In a recent list which I consulted, twenty-one works

were found in this section, and seven of them were sociological or economic and therefore not properly 'science' in the sense in which a scientist understands this word. The remaining fourteen, however, provide a most interesting selection. They are:

Boyle	*The Skeptical Chymist*
Darwin	*The Origin of Species*
Eddington	*The Nature of the Physical World*
Euclid	*The Elements of Geometry*
Faraday	*Experimental Researches in Electricity*
Galton	*Inquiries intoHuman Faculty*
Hahnemann	*Organon of the Rational Art of Healing*
Harvey	*The Circulation of the Blood*
Huxley	*Essays*
Huxley	*Lectures and Lay Sermons*
Lyell	*The Antiquity of Man*
Miller	*Old Red Sandstone*
Tyndall	*Glaciers of the Alps*
White	*The Natural History of Selborne*

To these one may add three volumes in the 'Travel' section:

Bates	*A Naturalist in Nicaragua*
Belt	*Voyage on the Amazon*
Darwin	*The Voyage of the* Beagle

and may note, in passing, that no scientist is included among the biographies.

Among the first fourteen, it is to be observed that Harvey's book is a translation of his *De Motu Sanguinis* and that the Euclid and the obscure Hahnemann, dealing as they do with mathematics and medicine, belong to a

slightly different category. The one characteristic that is common to all these seventeen books is that they are essentially readable, rather than world-shaking publications which heralded a new epoch. This is true even of Euclid, which in the history of book-production has sold more copies than any other book except the Bible; and of Galton's *Inquiries*, even though his biometry was quickly replaced by Mendelian, or Batesonian, genetics. The general impression made by a study of the selection is that on the whole they represent the more successful attempts to make 'Natural Science' a subject with which the sober-minded Victorian reader might seriously concern himself; and that as such they carried over a residuum of that appeal to the early years of the twentieth century. But it would be interesting to know how many biologists of to-day would think of reading Huxley or Lyell or Miller.

Of all these books, Charles Darwin's *On the Origin of Species by Means of Natural Selection*, to give it its full title, stands, of course, in a class by itself. Probably no other book and certainly no other scientific book, has produced anything like the disturbance in the minds of its readers, whether they were critics or supporters. It is difficult to-day, when the last of the dust of conflict has settled and the last sound of controversy has died away, to recall the bitterness of that historic battle between prejudice and reason; therefore there is every justification for quoting Dr C. E. M. Joad's forceful summary:

> In the Nineteenth Century the Church imprudently gave battle to science, particularly biological science. The battle was for the Church, a series of almost

continuous defeats. Rushing in where savants feared to tread, an army of unprepared and uninformed clergymen were beaten off the field by the withering fire of fact with which the biologists, the geologists and the physicists bombarded them. Rarely have controversialists chosen their ground so unwisely. Rarely has there been such a humbling of spiritual pride.

There is interest in a glimpse at the history of the book itself. The first edition appeared on 24th November, 1859, and consisted of only 1,250 copies. Six editions were called for during Darwin's lifetime and were produced with his own modifications and additions:

> Second edition in 1860, third edition in 1861, fourth edition in 1866, fifth edition in 1869, sixth edition in 1872.

A reprint of the first edition has recently been produced, and almost certainly no scientific work of the nineteenth century is read so often to-day, no book so unquestionably deserves the description epoch-making as does *The Origin of Species*.

The consequence of this is that *The Origin* sets a standard in the literature of science which few other books can hope to reach, but it provides the first clue that helps us to look for other classics of science and to recognise them when we find them. The feature of *The Origin*, apart from its intrinsic interest and its native merit, was that it told of Darwin's own work in his own words, showed us the facts which he had observed and the growth of his deductions from them. This is surely what should first be sought.

As has already been pointed out, the first intimation which the scientific public gets of any new work is usually from a paper in the pages of a scientific society's journal, but there have been occasions when the author has later taken the opportunity to gather together the whole story of the development of his subject into a book that can reach a wider circle of readers. To-day the nature of matter, or the structure of the atom as it is more often called, takes a prominent place in our thoughts, and there are countless scientists by no means senile, who can remember the work of Sir J. J. Thomson, and the discovery of a particle, the electron, whose weight was $\frac{1}{1850}$ that of a hydrogen atom. The early story of this can be read in Thomson's book *The Conduction of Electricity through Gases*, which must surely remain, for a long time, the authoritative account of a piece of purely academic work from which arose applications of an unsuspected magnitude.

Among other books in which, in the same way, the history of fundamentally important work is narrated by the scientist largely responsible for it are Dr F. W. Aston's famous *Isotopes* and Sir William Ramsay's *Gases of the Atmosphere*. Both these books are likely to live for generations to come; the value of isotopes is already established, and Ramsay's book, besides giving a historical account of the earlier investigations into the constitution of air, tells how one of the most surprising discoveries of the age was accompanied by the development of a technique in the manipulation of minute quantities of gas which has never been surpassed.

Clearly these books and others like them – Faraday's

Experimental Researches in Electricity is an example – owe their appeal in part to the intimate relation between the work and the man. At one moment the interest of the research is in the ascendant, at another it is the human side of the problem that holds us, the side that is more continuously dominant in biographies.

In the Biography section of *Everyman's Library* there are no lives of scientists, very possibly because the biography of a scientist is generally a serene record of a quiet life devoted to the pursuit of knowledge and the development of the scientist's own methods, providing less exciting reading than the turbulent and sometimes unedifying episodes which enliven the histories of travellers, poets and artists. Yet there are some lives of scientists that should be read by many and recommended to all.

Sir J. J. Thomson's *Recollections* gives the reader an insight into the administration first of a great laboratory, the Cavendish Laboratory, and next of a great college, Trinity, Cambridge, two institutions which can undeniably claim a world-wide reputation.

A discovery that has saved more thousands of lives than can easily be calculated was made when Ronald Ross, then a medical officer in the Indian Army, discovered that the malarial parasite lived in the mosquito as a secondary host which carried it from man to man. The story of Ross's life, called simply *Memoirs*, is one of the books whose interest becomes more compelling every decade that slips away.

These two examples are autobiographies, and the question as to whether a man is really the best judge of his own life work or not is one that can scarcely be

debated here. The alternative, the simple biography, will always have an assured place.

Among scientific biographies, that of Lord Rayleigh, by his son, stands high in the estimation of other scientists. This is not only because of the intrinsic importance of Rayleigh's researches, not only because of their relation to Ramsay's discoveries of the rare gases and not only because it paints a vivid picture of scientific genius; but also because it reveals so clearly to the unscientific reader, as well as to the scientist of humbler attainments, the difficulties that are encountered when a piece of practical work such as the weighing of a gas seeks a quantitative result with the highest possible degree of accuracy.

The lives of British scientists of such a quality as this are necessarily rare; but translation has made available the stories of Eve Curie and Gregor Mendel in books whose permanent value cannot be gainsaid.

★ ★ ★

These are books which must face the problem of making the doings, that is to say the actual laboratory operations, the ideals and the ideas of the scientist as clear as possible to that important personage who has been variously known as the man in the street, the general reader or the intelligent citizen. In other words these diverse individuals have to be shown the way in which the scientific mind works and the ends towards which it labours. If possible they must also be made sympathetic with the line of thought and appreciative of the aim or ambition. To do this successfully is often extremely difficult, for in the last analysis it means that scientific

conceptions must be expressed in non-scientific language and yet in language which is as accurate, as precise and as unambiguous as that of the scientist. Theoretically this is impossible, because of the associations which cloud the meanings of ordinary words; in practice the immiscibility of scientific and ordinary language is responsible for the difficulty of writing 'popular science', which becomes a craft of the most elusive nature.

Books that fall within this category belong to at least three classes. In the first are those written by competent scientists, dealing with matters with which they have first-hand acquaintance, and putting their expert knowledge before the wider audience described above. Perhaps the best example of such a book is Lancelot Hogben's *Mathematics for the Million*, a scientific best seller which expounds the principles of mathematics as an entrancing journey through strange pathways of thought and which thoroughly deserves its phenomenal success. Any scientist invited to join in the favourite pastime of choosing six books suited to the life of a maroon on a desert island would give it very serious consideration: he would undoubtedly be foolish not to include it.

To the same class belong the writings of Dr Jeans, who made the ideas of astronomers and cosmologists matters of widespread discussion: so too do a number of those books, from Tyndall's *Heat, a Mode of Motion* to Bragg's *World of Sound*, which owe their origin to lectures given at the Royal Institution.

In the second category are books also written by competent scientists but dealing with scientific topics outside their own speciality. For reasons which are obscure these books are seldom given a more than

temporary welcome and must be excluded from any consideration of the lasting literature of science. They do not compare well with the books in the third group, the works of the writers of scientific fiction.

The scientific novel either uses a scientific concept in a scientific way, as in Aldous Huxley's *Brave New World*, or it gives a picture of the impossible in a scientific disguise, as in H. G. Wells' *Food of the Gods* or *The Invisible Man*. The value of the former kind lies in the fact that they illustrate the impact of a strange scientific idea on the mind of the ordinary man; the latter are but fantasies, which happen to be scientific rather than anything else, and one cannot but feel that if any of these books survive it will be because of the story they tell and not because of their science.

★ ★ ★

This excursion from the realms of the strictly scientific serves to emphasise the principle enunciated at the beginning of this book, that the language of science is essentially informative; it cannot run in double harness with emotive language. In consequence, emphasis falls on the opinion that what characterises a classic of science is neither the intrinsic importance of its subject, nor its breadth of appeal, nor its readability, but its authoritative nature. This arises only from the years of specialisation which the writer has devoted to his subject, and which enables him to survey an intentionally limited portion of the field with meticulous attention to detail. It may be said with patronising implication that a specialist is one who knows more and more about less and less, but that is one of the ways in which science progresses, and

it is one of the qualities which give a scientific book a long life of usefulness.

It would be difficult to choose a better example of this than Prof. R. C. Punnett's *Mendelism.* Punnett was Professor of Genetics at Cambridge, and the book was published in 1905. In the next twenty years it passed through six large editions, including two complete revisions, and appeared as well in American, German, Swedish, Russian and Japanese editions, a record that few if any, other scientific books can show.

I have taken a book which has especially appealed to me ever since I attended the fascinating lectures of its illustrious author, but every scientist could suggest an alternative which has stirred his own imagination. Even a casual glance at the shelves of any science library will give the impression of a long list of obviously important works on a wide variety of specialised subjects, books on Catalysis or Valency, on Parasites or Arachnida, on Thermodynamics or Electrolysis, or Algae or Monocotyledons.

The fact is that here are to be found the real classics of science, both from the point of view of the scientist, because it is to these that he turns for help in difficulty, and from the point of view of the present book, because it is in these that the language of science can be studied in its proper environment. In a book written by a scientific authority we see a specialist working unhampered in a field in which he is master, the production of some of the corner-stones of knowledge.

Consider, in this respect, the publications of the Ray Society. This society was instituted in 1844 for the publication of works on natural history, of so limited

appeal that they would not otherwise be able to find their way into print. One or two volumes are produced each year; a large proportion of them deal with our native fauna and the rest are botanical. Together they form a set of monographs whose value is universally recognised. Also they provide some of the best examples of the literature of science in the sense in which it is discussed here.

* * *

It may be repeated that whereas in *The Voyage of the Challenger* or *The Expanding Universe*, the appeal is appreciably to the imagination and the emotions, in a monograph on crystals or fungi it is solely to the desire for information. Further, this desire is invariably strongest and most urgent in students of all ages, and information is most concentrated in text books and is most commonly obtained from them.

Text books are often decried. Many generations of Cambridge men have rejoiced in the frequent reiteration by the great Dr H. J. Fenton of the phrase, 'It's on page one of the text book', and will recall the triumph with which in a reference to hydrogen he would say, 'This is really page one'. Text books may seem to be a curious kind of book for which to claim the description of 'literature of science', and it is true enough that they are seldom literary. But the best of them are great successes, they sell in immense numbers and they exert a wide influence. Probably the most conspicuous example of this is the familiar *Organic Chemistry* of W. H. Perkin and F. S. Kipping, published by W. and R. Chambers in 1894. A revision in three volumes was produced in 1949,

and one of its reviewers remarked with unquestionable truth that there could scarcely be a chemist in Britain who has not either used it himself or been taught by one who had. Probably G. S. Newth's *Inorganic Chemistry* would justify the same comment.

In a discussion of influential text books mention must be made of that almost unparalleled series of books which, about the beginning of the present century, were universally to be recognised by their characteristic green binding. I well remember an occasion many years ago when, carrying one of them, I met a friend who glanced at the cover: 'Evidently published by Macmillan', he said.

The record of that famous firm in producing scientific text books is little short of amazing when one considers the short space of time over which these books appeared, their quality and the reputation they deservedly enjoyed. Between 1890 and 1909 there were seen

Preston	*The Theory of Heat*
Preston	*The Theory of Light*
Walker	*Introduction to Physical Chemistry*
Nernst	*Theoretical Chemistry*
Ostwald	*Principles of Inorganic Chemistry*
Parker & Haswell	*Text Book of Zoology*
and, in ten volumes	*The Cambridge Natural History*

It should be added that within the twenty years mentioned all these books passed into further editions – the famous 'Walker's *Physical*' for instance, reached its fifth edition in 1909. Further, there is no reason to suppose that the list is complete, but there is no doubt about the quality of those included. As to their reputa-

tion, I can remember one of His Majesty's Inspectors of Schools asking me whether they were to be found on the shelves of a certain science library: 'Even to look at the backs of such books is an education,' he said.

★ ★ ★

Much the same position is held in America to-day by the scientific texts published by the house of McGraw-Hill. No matter in what branch of science a student is most keenly interested he is sure to know the familiar canvas cover and red label that is evidence of a McGraw-Hill book. In the 1952 catalogue of that firm over three hundred titles are included in the science sections: they average over six hundred pages in size. Among so large a number there must inevitably be some fluctuation in quality, but even so the influence of these books on the scientific education of American youth must be immense.

In Britain to-day the outstanding science text book is the majestic *Comprehensive Treatise on Inorganic Chemistry* produced by J. W. Mellor. It numbers fifteen large volumes and includes, one might almost say, everything. In having such a book available the student of chemistry is fortunate; he is more favoured than the zoologist, who in fact has never known in this country a text book of zoology produced on a comparable scale.

This surprising fact is a reproach both to the enthusiasm of our zoological authors and to the enterprise of our publishers; it appears to be a matter of indifference that British zoologists should grow up to respect the monumental *Handbuch der Zoologie* edited in Germany. It is surprising to see the production by

post-war France of a magnificent *Traité de Zoologie*, which is expected to fill seventeen volumes. Perhaps an overtaxed overcrowded Britain cannot hope to reach such a standard of attainment, and yet it seems as certain as such things can be that a Zoology, in, say, six volumes would be enthusiastically welcomed by English-speaking scientists everywhere, and would repay the publisher who was courageous enough to produce it. A competent editor would not be difficult to find.

The appreciation which such a work would receive can be judged by that shown for the ambitious *New Naturalist* series. When in 1945 Dr E. B. Ford's *Butterflies* was published, it was evident that it heralded a project hitherto unfamiliar in this country. From that beginning the series has progressed with no decline in standard; it has indeed deserved the description of 'one of the great publishing ventures of the age'.

* * *

There are well-known difficulties in attempting a judgment of the present age, and any opinions expressed in this closing paragraph can be no more than a tentative belief. Many years have passed since J. M. Barrie wrote that, 'the Man of Science appears to be the only man who has something to say, just now – and the only man who does not know how to say it'. In the meanwhile the scientist has certainly not perfected his command of English prose, nevertheless it is true that the books of the scientists compare favourably with the books of any other group of thinkers. It is fortunately possible to turn to a scholar of the widest learning to find the names of the books which support this opinion. Canon C. E.

Raven, writing in 1943 in *Science, Religion and the Future*, was inspired to give us his choice of 'five books of real importance'. They were:

Lloyd Morgan	*Emergent Evolution*, 1923
Eddington	*The Nature of the Physical World*, 1928
Whitehead	*Science and the Modern World*, 1925
Haldane	*The Sciences and Philosophy*, 1929
Smuts	*Holism and Evolution*, 1926

Undoubtedly they form an imposing quintet, and it may well be questioned whether the historians or the theologians or the artists or any other category of scholars can point to a finer group of written works.

Books of this character, supported by many others that have barely fallen short of the same high standard of excellence, have inspired the opinion of a well-known critic in the following estimate of modern scholarship. 'In prose,' he says, 'the time is one of ability and judgment. . . . It is from the scientists that so many of our finest books have come, fine in their plan, in their substance, in their development and in their continuous clarity.' The description is just, and the praise is subtly apportioned, for it more than half conceals the modern preponderance of thought and matter over style, or the accepted subordination of style to content.

This book has tried to demonstrate the existence of a real language of science and to detect something of its strength and its weakness. Its strength will be enhanced, its weakness will be concealed, and its power for good will become greater as scientists turn their abilities to using it more effectively.

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